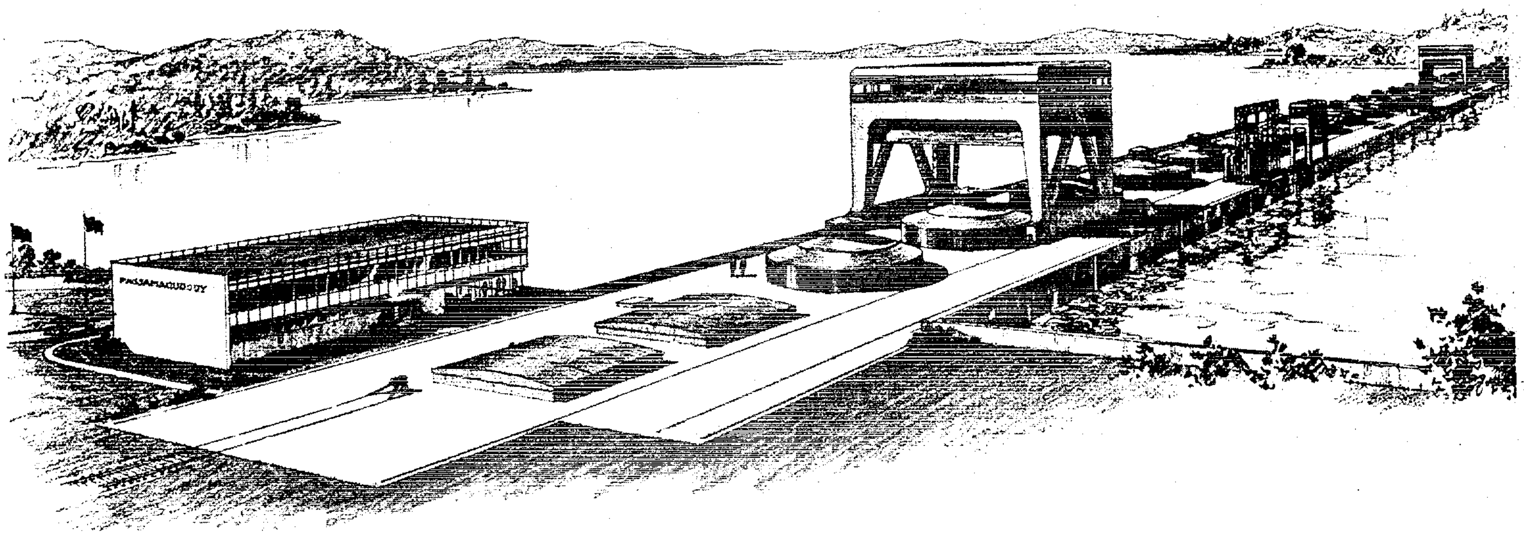
INVESTIGATION OF THE INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT



APPENDICES

1. Topography and Underwater Mapping
2. Geology, Foundations and Materials
3. Observation and Prediction of Tides

REPORT TO THE INTERNATIONAL JOINT COMMISSION BY THE INTERNATIONAL PASSAMAQUODDY ENGINEERING BOARD

October 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

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REPORT TO

INTERNATIONAL JOINT COMMISSION

ON

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 1

TOPOGRAPHY AND UNDERWATER MAPPING

BY

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

WASHINGTON, D. C.
OTTAWA, ONTARIO

OCTOBER 1959

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 1

TOPOGRAPHY AND UNDERWATER MAPPING

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APPENDIX 1

TOPOGRAPHY AND UNDERWATER MAPPING

1-01 PURPOSE

This appendix presents data on topography and hydrography collected for the proposed international Passamaquoddy tidal power project and its auxiliary projects. Marine mapping operations are described which were undertaken to provide data on the nature and thickness of underwater overburden.

1-02 SCOPE

This appendix contains a summary of prior studies, existing data, new topographic and hydrographic surveys, and information on subaqueous overburden determined by methods other than conventional core borings. Existing information was gathered early during the survey to serve as the basis for the studies to determine the most favorable tidal power project arrangement. These studies are described in appendix 5, "Selection of Plan of Development." Concurrent with these studies and guided by them, additional field explorations as described in this appendix were undertaken for the current tidal power survey. Information from existing sources and the new data were compiled into a single series of maps which were used as the basis for the design and cost estimate for the selected layout of the tidal power project diagrammed on plate 1-1. These maps are presented in this appendix. Maps used to determine areas and storage capacities of the pools are presented in appendix 4, "Basic Hydrologic Data," and maps used in tidal project arrangement studies are described in appendix 5. This appendix also describes topographic data collected for the study of auxiliary power projects.

1-03 EXISTING DATA

a. General Topographic Surveys. Topographic surveys of the entire region of the tidal project and its auxiliaries have been conducted by the U.S. Geological Survey and the Canadian Department of Mines and Technical Surveys. Results of these surveys are available in published quadrangle sheets. The U.S. Geological Survey sheets have been prepared to a horizontal scale of 1 to 62,500 with a contour interval of 20 feet. The Canadian quadrangle sheets have a horizontal scale of 1 to 50,000 with a contour interval of 50 feet.

b. Hydrographic Surveys for Navigation. The entire area of the tidal power project has been surveyed for navigation at various times since 1866 by the U.S. Coast and Geodetic Survey, the International Boundary Commission, the Canadian Hydrographic Service, and British Admiralty. The results of these surveys, compiled as Hydrographic Chart 801 of the U.S. Coast and Geodetic Survey, have been used for general studies. Copies of many of the manuscript survey sheets were used for detailed studies because of the greater number of soundings shown.

c. Investigation by Cooper, 1926-28. Dexter P. Cooper, during the period 1926-28, surveyed the pool areas and the underwater structure sites and made a reconnaissance of the approach channel areas. Contour maps of the structure sites were prepared to a scale of 1 inch equals 200 feet with contour interval of 5 feet.

d. Investigation by Corps of Engineers, U.S. Army, 1935-37. As a part of the Passamaquoddy tidal power project started by the Corps of Engineers, U.S. Army, in 1935, additional topographic and hydrographic surveys were made for structures proposed at that time for the single-pool project entirely within the United States.

e. Navigation Channel Surveys by Corps of Engineers, U.S. Army. In connection with investigation of navigation channels within the project area, the Corps of Engineers, U.S. Army, conducted local surveys in Lubec Channel in 1949 and near Clark Ledge, just north of Eastport, in 1956.

f. Sonic Survey, 1951. In the summer of 1951, the Water Resources Division of the U.S. Geological Survey, in cooperation with the Corps of Engineers, U.S. Army, made geologic and geophysical studies designed to (1) test the effectiveness of sonic methods in determining distribution and thickness of unconsolidated underwater sediments, and (2) discover as much as possible about such sediments in the Passamaquoddy Bay area. Eight areas were surveyed as indicated on plate 1-1. Only two of these cover structure sites of the plan of development used in this survey. Fathometer investigations were conducted from a converted cargo boat. Horizontal positions were fixed by sextant observations of previously established shore stations. The sounding equipment recorded only depth from the water surface which was continually and rapidly changing because of the large tides which prevail in the area. The soundings were corrected to mean sea level by reference to tide levels measured continuously at several tide gages established for the survey. Two sounding units were used. One was a special unit developed in accordance with U.S. Geological Survey specifications. It emitted a high-power, low frequency signal intended to penetrate the underwater overburden. The other unit was a commercial instrument of less power and higher frequency which was used to determine water depths. Detailed description of equipment, procedures, and results obtained is contained in a brochure by the Water Resources Division of the U.S. Geological Survey dated December 1952, entitled "Preliminary Report on the Passamaquoddy Bedrock Survey, July - August 1951."

g. Saint John River Survey at Rankin Rapids, 1951. The prospective river hydropower site at Rankin Rapids on the Saint John River, about 3 miles upstream from St. Francis, Maine, was surveyed in 1951. Maps prepared at that time were included in an interim report to the International Joint Commission by the International Saint John River Engineering Board.

1-04 NEW TOPOGRAPHIC AND HYDROGRAPHIC SURVEYS

a. General. New topographic surveys were made as part of the field investigation in 1956-57 to supplement existing data and to extend coverage to new areas considered for prospective development.

b. Aerial Surveys, 1956. Aerial surveys were conducted by Aero Service Corporation of Philadelphia, Pennsylvania, in 1956, covering the Canadian portion of the tidal power project and the site of the proposed auxiliary pumped-storage project in the Digdeguash River basin in New Brunswick. Maps of both areas were prepared to a horizontal scale of one inch equals 400 feet with contour intervals of 10 feet.

c. Ground Surveys, 1956-57. Ground surveys were made by the Eastport field office staff of the Passamaquoddy survey work group to obtain more detailed information on specific areas considered for project structures. Also, this field staff performed basic horizontal and vertical control surveys to correlate independant surveys within the project area.

d. Hydrographic Surveys. Limited hydrographic surveys were made by the Eastport field office staff to supplement and extend information from other sources. Water depths were determined with a Bludworth Marine Fathometer. Observed depths were adjusted to elevations below mean sea level by adding or subtracting tide levels prevailing at time of observation. The hydrographic survey boat was located by two transits from shore stations.

1-05 UNDERWATER MAPPING, FAIRCHILD CONTRACT, 1957

a. General. One of the important features of the international Passamaquoddy tidal power survey has been the investigation of the foundation conditions for the deep tidal dams required. The high cost of conventional core borings in deep water, with fast tidal currents, led to consideration of geophysical exploration. The sonic exploration method was selected, particularly in view of the apparent success of preliminary work of this type performed in 1951. The field explorations of this program were planned to precede the deep water drilling described in appendix 2, "Geology, Foundations and Materials," and to provide guidance for locating the deep water drill holes. As a result of exploratory conferences, the Fairchild Aerial Surveys, Inc., of Los Angeles, California, was selected to perform the sonic work.

b. Scope of Work. The contract with Fairchild Aerial Surveys, Inc., involved mobilization of equipment and conducting sonic surveys to determine top of overburden, top of bedrock, and to obtain and interpret all data which may indicate changes in character of overburden in several separate areas in the project vicinity. Approximately

100 range miles of profiles were surveyed. Principal items of equipment required by the contract included a sonic exploration device of the best modern technical design, electronic positioning equipment for determining horizontal position of the soundings, and a power-operated boat adequate to perform the exploratory operations. The contract further provided for development of contour maps, geological profiles, and a final report including comments on accuracy and reliability of the results obtained.

c. Marine Sonoprobe. Fairchild, Inc. used the Marine Sonoprobe, a reflecting seismograph, for the survey. This equipment emits into the water a low frequency sound wave of sufficient energy to penetrate subaqueous materials, and measures the time of return of the reflected sound wave. The distance of wave travel in the various materials is determined from the measured time. The manufacturer indicated that this device generates a sound wave with a dominant frequency of about 3,800 cycles per second at 12 pulses per second. The return wave is converted to electrical signals producing a record on electrosensitive paper on which the vertical scale indicates distance below water surface based on time of sound wave travel in sea water (4,800 feet per second). During actual service, it was found that the sound wave had somewhat less than 1,000 watts of energy and was composed of a spectrum of frequencies of 900 to 9,000 cycles per second with dominant frequency of approximately 3,800 cycles. About one-half of the energy was contained in a cone of 30° solid angle. These characteristics restricted the energy of the input wave of the desired relatively low frequency which would penetrate overburden and be reflected to the receiving transducer. The electrical signals being fed to the Sonoprobe chart were under constant surveillance on an oscilloscope which was limited to viewing 100-foot increments of vertical profile. This restriction limited opportunity to follow trends of more than one interface when more than a single 100-foot depth range from water surface was involved. The instrumentation permitted the operator to arbitrarily filter out a narrow band of frequencies for recording without any record of filter settings. The frequent to nearly continuous manipulation of instrument controls, attempted for the purpose of improving and clarifying the sonic record, resulted in changes in markings and shadings on the Sonoprobe chart. These changes tended to obscure the record of reflected sound waves.

d. Electronic Positioning Equipment. The technical requirements for the electronic positioning equipment were established in preliminary discussions and conferences for negotiation of a formal contract. The MORAN positioning system, which was used, permitted instantaneous location of the survey boat with respect to previously established shore stations. The boat positions were plotted on a control boat sheet by a mechanical tracking device. Within the limits of accuracy of $\pm$ 50 feet, the positioning system permitted rapid evaluation of the area covered by the survey operations and thereby facilitated establishment of intermediate or additional coverage as necessary while the survey boat was still operating in one locality.

e. Survey Boat. The survey boat was 26 feet long and had the lines of a conventional cabin cruiser with a flying bridge. The hull was of fiber-glass construction. A single inboard engine drove the craft and charged the large bank of storage batteries required for the electronic equipment. An additional motor generator set was added when it was found that sufficient battery charge could not be maintained during survey operations. The amount of equipment required and the need for mounting it on tables loaded the boat in such a manner that safe operation was assured only when tidal currents and wind conditions were moderate to favorable. The boat also lacked adequate power for the tidal currents encountered even after the motor-generator set was added to relieve the main engines of some of the battery charging load. Full power operation of the motors was found to generate so much noise that it interfered with satisfactory operation of the sonic equipment. Even under normal operating conditions the noise level in the cabin was so high that an intercommunication system with earphones was necessary for communication between personnel on the boat. Normal boat noise and vibrations affected the Sonoprobe chart adversely by introducing interference which obscured the record.

f. Results Obtained. A large portion of the Sonoprobe charts showed only one trace, i.e., the water bottom. The remainder showed two traces, or two diverging traces, the lower one of which became indistinct as its depth below the upper trace increased. In no case did more than two original traces appear. Repeated reflections of the sound wave produced multiples of the original Sonoprobe trace. These multiples were similar to the original traces but fainter, and were ignored in the interpretation. Where two original traces appeared it was presumed that the upper one represented the top of overburden and the lower trace indicated the boundary between overburden and rock. Where only one trace appeared, adjacent portions of the Sonoprobe chart were examined to determine whether a second trace existed there and had merely faded out in the zone in question. If this was the case, the material under the single trace was presumed to be overburden. Overburden was also presumed if data from deepwater drilling operations (appendix 2) indicated its presence. Where only one Sonoprobe trace was in evidence, the depth of overburden was based on geologic inference supplemented by data from deep water borings. The deepwater drilling operations previously referred to indicated soft clay overburden in the Indian River area, in the Eastport to Treat Island area, and in Quoddy Roads. The Sonoprobe was found to yield two traces consistently in these areas. In areas where the drilling operations indicated a granular overburden, the Sonoprobe was capable of producing only one trace. On this basis, the existence of two traces was considered indicative of a soft clay overburden and one trace either granular material or rock.

The Sonoprobe instrument was designed to indicate depths accurately on the calibrated chart if sound velocity through the medium involved was 4,800 feet per second. This was correct for sea water, so the depth of water was accurately represented. The velocity of sound in the material between the first and second traces is not accurately known for the particular materials involved at the site. Technical literature indicates that sound velocity in clay is generally about that in sea water, but in granular materials it is substantially greater. Two traces were taken to indicate a clay overburden in which sound velocity is essentially that in water. Because the small velocity differences which might exist would not affect the accuracy of the work, no correction to the apparent thickness of overburden indicated by the Sonoprobe chart was made in preparing the maps and profiles. The depths indicated on the Sonoprobe charts were reduced to mean sea level by adding or subtracting the tide level prevailing at the time of the particular sounding to secure elevation below mean sea level.

The underwater information from Sonoprobe charts was added to maps of the shoreline and above water topography, scale 1 inch equals 400 feet, prepared from aerial photographs by the Aero Service Corporation, Philadelphia, Pennsylvania, for the current survey in 1956. Samples of the underwater topography, a profile, sonoprobe chart, and photographs of the accompanying oscilloscope trace are shown on plate 1-2. The results of the survey shown on the maps and profiles developed by the Fairchild company furnish (a) accurate information on the bottom level, (b) relatively accurate indication of whether the water bottom is or is not soft clay, (c) speculative information on whether the water bottom is rock or granular overburden, (d) relatively accurate information on thickness of clay overburden, (e) speculative information on thickness of granular overburden, and (f) no information to indicate whether layers of different materials may occur in the overburden. The apparent ability of the Sonoprobe instrument to indicate the presence of a soft clay foundation was a considerable advantage because such foundations are unfavorable for the tidal dams. The inability to distinguish between rock and granular overburden was not as serious a handicap as might be expected because either are suitable as foundations for the tidal dams.

1-06 DEVELOPMENT OF MAPS FOR TIDAL PROJECT

a. General. The maps prepared by the Fairchild, Inc., (the Aero Service Corporation land topography and shoreline, supplemented by Sonoprobe underwater data) were further modified to incorporate the remainder of the previously described underwater information. In combining information from the various sources it was necessary, at some locations, to make adjustments. These were made by giving the most consideration to the latest or more reliable records. Bottom contours from the various sources were found to be reasonably consistent, and only nominal and occasional adjustments were made. Contours of bedrock surfaces are based primarily on the 1957 Sonoprobe survey coordinated with data from the subaqueous boring program. Maps for the areas in which structures for the proposed tidal power plant would be located are included as plates 1-3 through 1-8. Comments on underwater mapping in the several project areas follow.

b. Letite Passage. Underwater mapping of the Letite Passage area is based on investigations by Cooper, the 1951 and 1957 sonic explorations, fathometer survey by the Passamaquoddy survey staff, and one core boring. Composite results are shown on plate 1-3. Topography in the proposed structure area is very irregular, valley walls are steep in near shore areas, and bedrock is exposed to a considerable extent. Overburden is confined largely to the submerged valley bottom, with small deposits in localized rock pockets and some shallow beach deposits. The 1957 Sonoprobe survey did not detect overburden in the valley bottom in the proposed structure area but geological evidence indicates that considerable granular material would occur in irregularities in the bedrock surface and in areas where tidal currents are weak. The 1951 sonic survey indicated that a few feet of overburden, presumed essentially granular, occurs in the valley bottom between Thum Cap Island and Dry Ledge where filling gates would be located. This indication was confirmed by core boring number 201-D which encountered 6.8 feet of sand, gravel, and cobbles. In the channel between Dry Ledge and Mc Master Island the 1951 sonic survey indicated about 75 feet of overburden, also presumed granular, but this observation has not been supported by any other data. A tidal dam would be constructed in this reach and, as previously indicated, either granular overburden or rock would provide an adequate foundation for this structure.

c. Little Letite and Pendleton Passages. Investigations made in the Little Letite and Pendleton Passage areas by Cooper, the 1957 Sonoprobe survey, and the Passamaquoddy survey staff indicated relatively shallow water passages as shown on plate 1-4. Abundant rock outcrops occur along all adjacent shore lines and in water areas. As no appreciable amount of soft marine silt or clay was discovered, it was concluded that any overburden in proposed structure areas would be a relatively thin deposit of granular type material which would not be adverse to the tidal dams planned in these areas. Contours of top of rock have not been determined because this information is not needed for developing the designs and estimates for the tidal dams involved.

d. Head Harbour Passage. The first investigation specifically for a tidal power project in the Head Harbour Passage vicinity was the 1951 sonic study which was largely experimental and covered a relatively small area. The 1957 Sonoprobe survey provided substantial coverage of the area and was supplemented by a fathometer survey by the staff of the Eastport field office. Additional information was obtained from subaqueous borings. Underwater contours developed from these surveys are shown on plate 1-5. Extent and thickness of overburden in this area were not clearly defined by the Sonoprobe survey and the thickness appeared generally less than indicated by the 1951 sonic survey. Therefore, contours of top of bedrock have been determined with reliance on the very few core borings in the vicinity and on other geological evidence. The 1957 Sonoprobe survey did not indicate the presence of soft surface deposits here as it had at several other locations. On this basis, the overburden indicated in the areas shown on plate 1-5 has been presumed to be principally granular in nature. Two specific exceptions are noted. The first is a soft surface layer just east of the proposed tidal dam between Pope Islet and Indian Island. This deposit was identified by the Sonoprobe survey (see plate 1-2). The second is a layer of soft material buried under granular material in the bottom of the deep channel between Campobello and Green Islands which was not detected by the Sonoprobe survey. The influence of this clay on the tidal dam proposed in this reach is discussed in appendix 9, "Tidal Dams and Cofferdams." At the proposed gate location between Pope and Green Islets bedrock apparently occurs with little or no overburden. The underwater topography along the shore of Campobello Island was determined as a basis for the design and estimate of the navigation lock proposed for this location.

e. Western Passage and Indian River. Western Passage carries most of the tidal inflow and outflow from Passamaquoddy Bay; and portions of its underwater areas have been mapped during all investigations of the tidal power projects except for the single-pool plan studied by the Corps of Engineers, U.S. Army, in 1935-36. The Indian River area came into consideration only during the current investigation. Contours of top of overburden and top of bedrock, for both of these areas, are shown on plate 1-6. Information from the 1957 Sonoprobe survey, as to extent and thickness of overburden, was not conclusive. Overburden deposits shown on plate 1-6 have been determined, to a considerable degree, from geological evidence and a few core borings. A tidal dam would be located across Western Passage where available evidence shows granular underwater overburden. In the Indian River channel between Deer and Indian Islands, the 1957 Sonoprobe survey indicated some soft sediments which were confirmed by core boring number 110-D. These data also indicated the extent of the clay overburden. It was found possible to minimize this unfavorable foundation by shifting slightly the alinement of the tidal dam proposed for this location. The shore line is partly rock outcrop and partly in beaches. The latter are of granular material which extends to unknown depths. These deposits are the result of the continual process of natural erosion and probably connect with the deeper sediments in many places. Underwater topography was developed along the shore of Deer Island Point and on Moose Island to permit design and estimate of the filling gates and navigation locks proposed at these locations.

f. Carryingplace and Johnson Coves. The area, including Carryingplace and Johnson Coves, has been intensively investigated for a proposed tidal powerhouse and its associated channels by Cooper; by the Corps of Engineers, U.S. Army, in 1935; and during the current tidal power survey. The underwater mapping shown on plate 1-7 reflects the composite results of the several investigations. The nature and extent of overburden have been explored by sonic methods and also by direct penetration by several core borings and many wash borings.

g. Quoddy Roads. Underwater mapping, shown on plate 1-8, is for the proposed Quoddy Roads tidal dam and the navigation lock. The mapping is the result of the 1957 Sonoprobe exploration, extended by the fathometer survey by the staff of the Eastport field office and correlated with limited core boring data. In this area, the Sonoprobe survey produced a reasonably well-defined indication of a subaqueous surface layer of soft sediment which was confirmed by core boring number 107-D.

1-07 MAPS FOR AUXILIARY PUMPED-STORAGE PROJECT

Maps prepared by the Corps of Engineers, U.S. Army, in 1935-37 were found entirely adequate for current studies of prospective auxiliary pumped-storage project sites at Haycock Harbor and near Calais in Maine. Maps prepared by Aero Service Corporation were used for studies pertaining to the Digdeguash site in New Brunswick with some supplemental details obtained from surveys by the Eastport field office staff.

1-08 MAPS FOR AUXILIARY RIVER HYDRO PROJECT

Maps of the Rankin Rapids site on the Saint John River developed for the interim report to the International Joint Commission, previously cited, were sufficient for present studies of that site. Studies of the Big Rapids and Lincoln School sites, in adjacent reaches of the Saint John River, were based on topography shown on U.S. Geological Survey quadrangle sheets. Supplemental profiles were obtained from surveys performed by the Eastport field office staff.

APPENDIX 1

PLATES

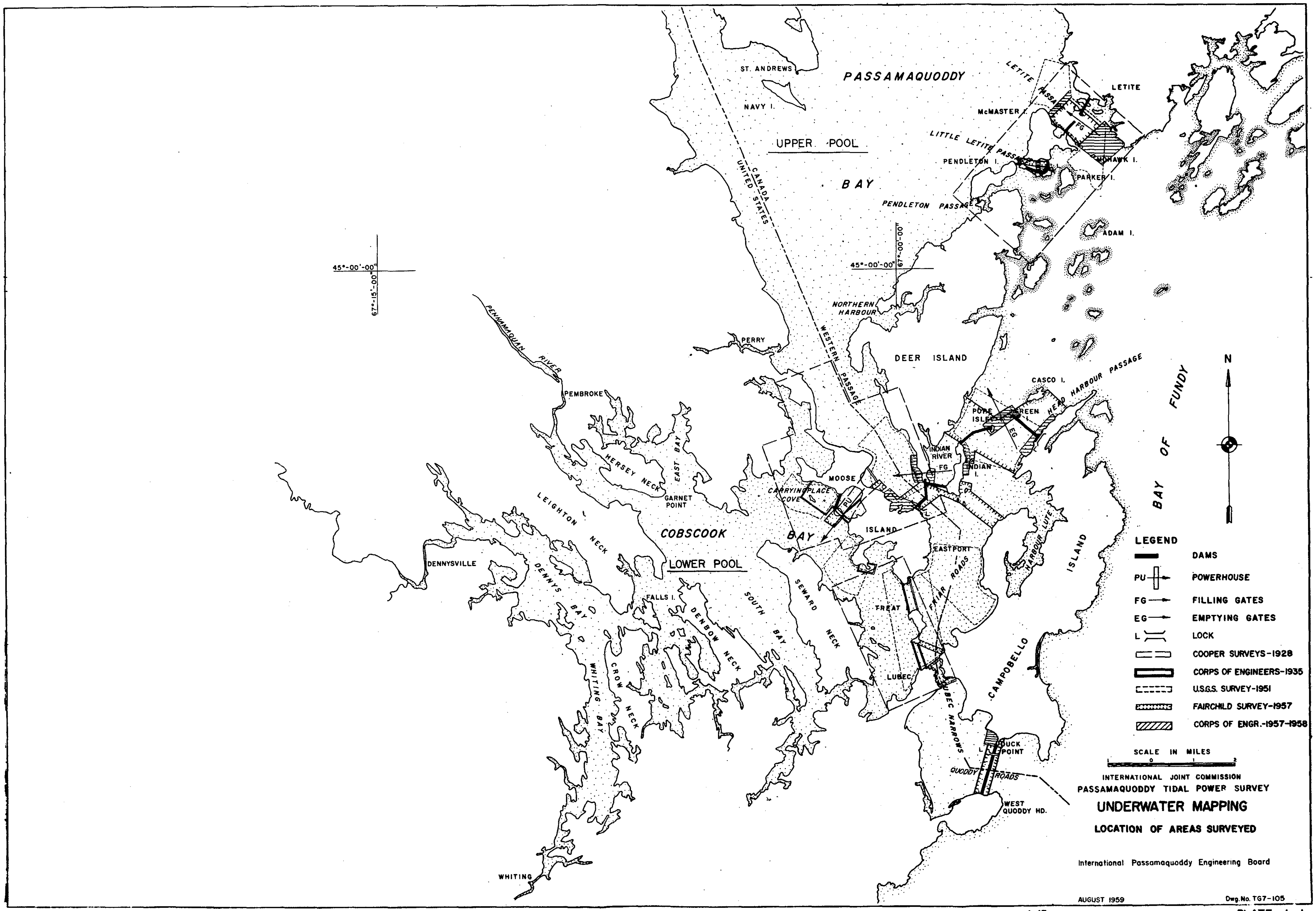
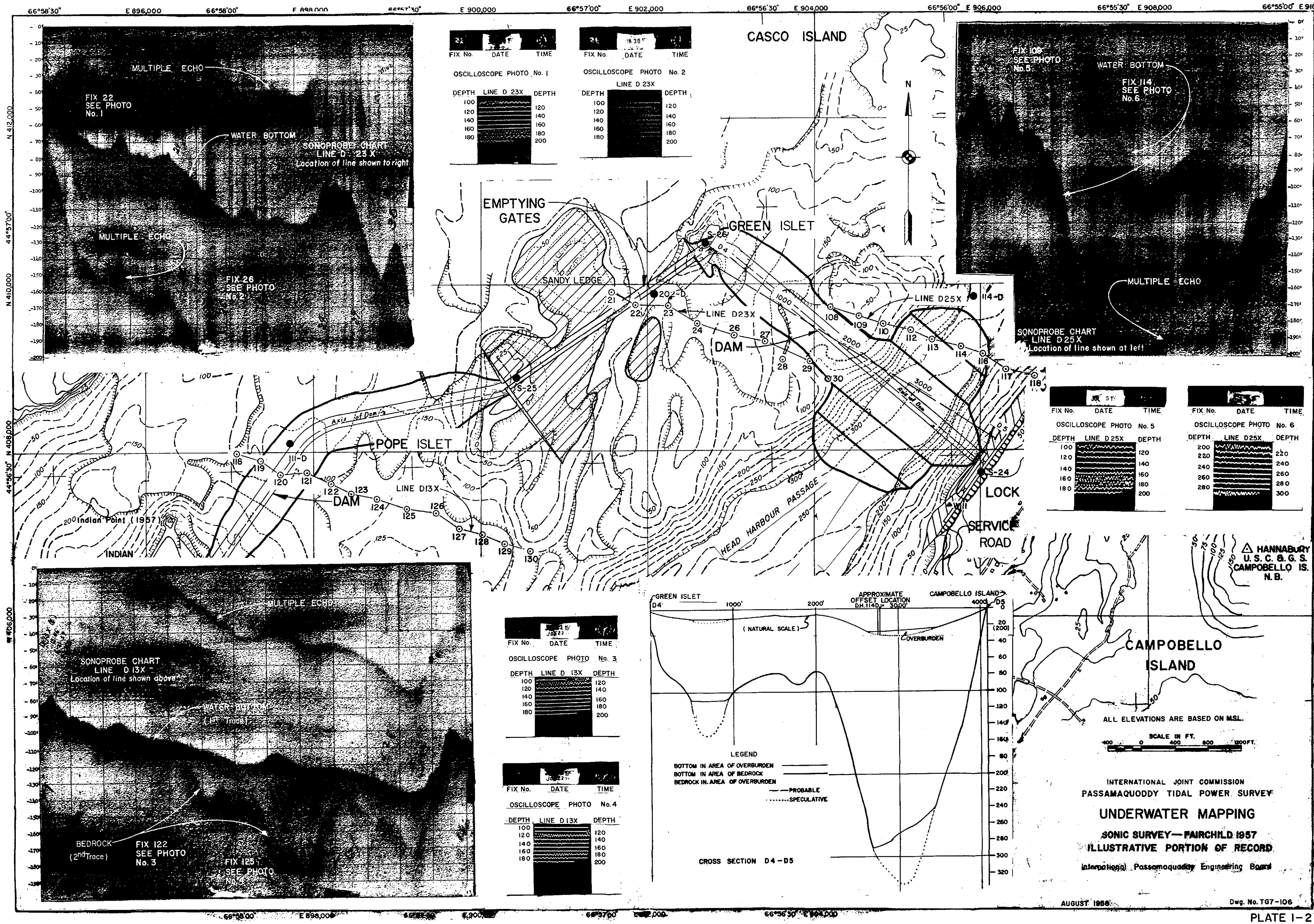
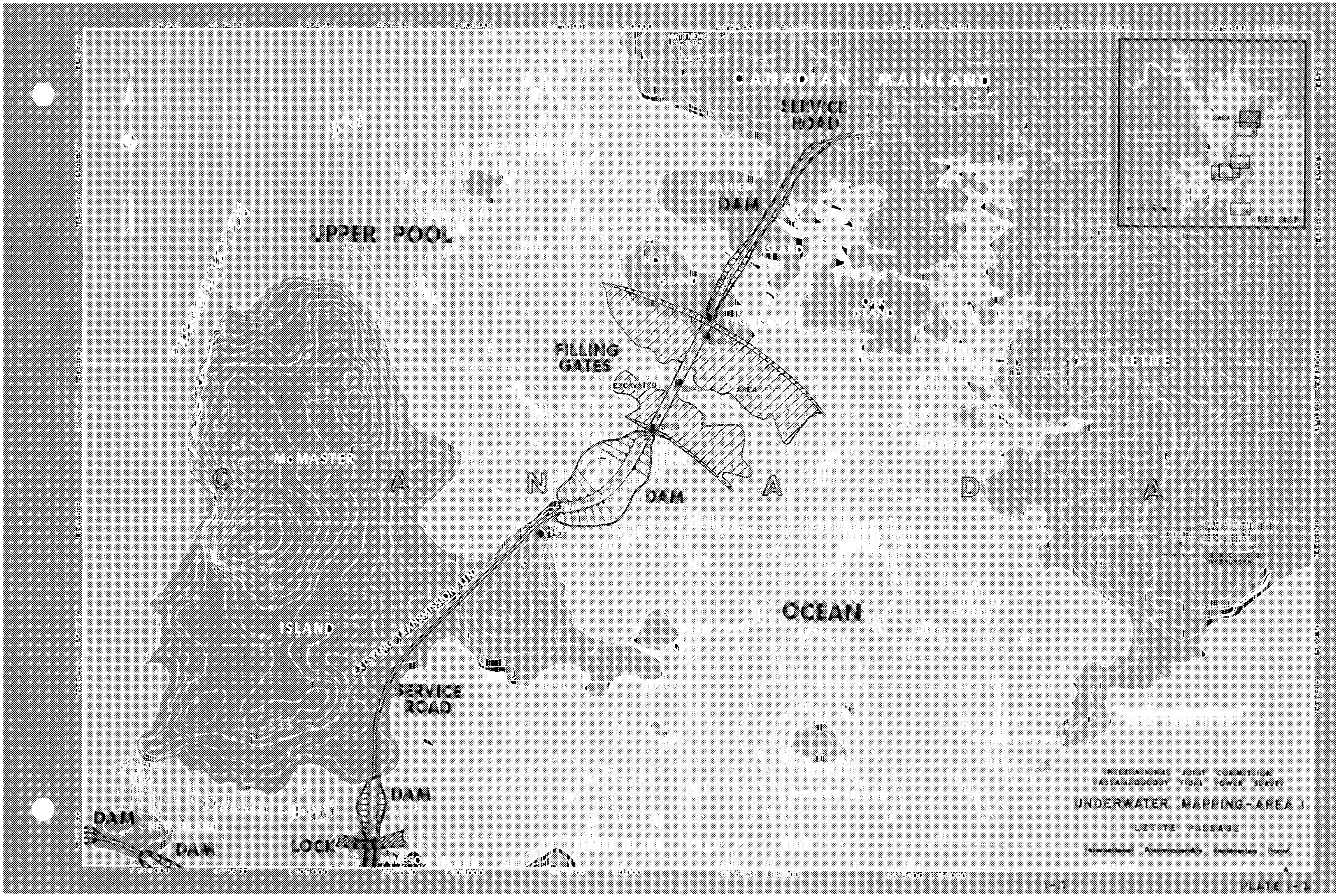

PASSAMAQUODDY
UPPER POOL
BAY
ST. ANDREWS
NAVY I.
CANADA
UNITED STATES
LETITE PASSAGE
LETITE
McMASTER I.
LITTLE LETITE PASSAGE
PENDLETON I.
MOHAWK I.
PARKER I.
PENDLETON PASSAGE
ADAM I.
45°-00'-00"
67°-00'-00"
67°-15'-00"
NORTHERN HARBOUR
WESTERN PASSAGE
PERRY
DEER ISLAND
CASCO I.
HEAD HARBOUR PASSAGE
BAY OF FUNDY
N
PENNAMAQUAN RIVER
PEMBROKE
INDIAN RIVER
INDIAN I.
HERSEY NECK
EAST BAY
GARNET POINT
MOOSE
CARRYING PLACE COVE
ISLAND
LEIGHTON NECK
COBSCOOK
BAY
LOWER POOL
EASTPORT
DENNYSVILLE
DENNYS BAY
FALLS I.
DENBOW NECK
SOUTH BAY
SEWARD NECK
TREAT
FRIAR ROADS
HARBOUR LUTE
ISLAND
CAMPOBELLO
WHITING BAY
CROW NECK
LUBEC
LUBEC NARROWS
DUCK POINT
QUODDY ROADS
WEST QUODDY HD.
WHITING
LEGEND
DAMS
PU POWERHOUSE
FG FILLING GATES
EG EMPTYING GATES
L LOCK
COOPER SURVEYS-1928
CORPS OF ENGINEERS-1935
U.S.G.S. SURVEY-1951
FAIRCHILD SURVEY-1957
CORPS OF ENGR.-1957-1958
SCALE IN MILES
0 1 2
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING
LOCATION OF AREAS SURVEYED
International Passamaquoddy Engineering Board
AUGUST 1959
Dwg. No. TG7-105

PLATE I-1



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING
SONIC SURVEY—FAIRCHILD 1957
ILLUSTRATIVE PORTION OF RECORD
International Passamaquoddy Engineering Board
AUGUST 1958
Dwg. No. TG7-106
ALL ELEVATIONS ARE BASED ON M.S.L.
SCALE IN FT.
CASCO ISLAND
GREEN ISLET
EMPTYING GATES
SANDY LEDGE
DAM
POPE ISLET
INDIAN
Indian Point (1957)
HEAD HARBOUR PASSAGE
LOCK
SERVICE ROAD
CAMPOBELLO ISLAND
HANNABURY U.S.C. & G.S. CAMPOBELLO IS. N.B.
Axis of Dam
LINE D23X
LINE D25X
LINE D13X
SONOPROBE CHART LINE D 23 X Location of line shown to right
MULTIPLE ECHO
WATER BOTTOM
FIX 22 SEE PHOTO No. 1
FIX 26 SEE PHOTO No. 2
SONOPROBE CHART LINE D 25 X Location of line shown at left
FIX 109 SEE PHOTO No. 5
FIX 114 SEE PHOTO No. 6
SONOPROBE CHART LINE D 13X Location of line shown above
WATER BOTTOM (1st Trace)
BEDROCK (2nd Trace)
FIX 122 SEE PHOTO No. 3
FIX 125 SEE PHOTO No. 4
OSCILLOSCOPE PHOTO No. 1
OSCILLOSCOPE PHOTO No. 2
OSCILLOSCOPE PHOTO No. 3
OSCILLOSCOPE PHOTO No. 4
OSCILLOSCOPE PHOTO No. 5
OSCILLOSCOPE PHOTO No. 6
FIX No. DATE TIME
DEPTH
CROSS SECTION D4-D5
GREEN ISLET
APPROXIMATE OFFSET LOCATION
CAMPOBELLO ISLAND
(NATURAL SCALE)
OVERBURDEN
LEGEND
BOTTOM IN AREA OF OVERBURDEN
BOTTOM IN AREA OF BEDROCK
BEDROCK IN AREA OF OVERBURDEN
PROBABLE
SPECULATIVE

PLATE I-2


CANADIAN MAINLAND
SERVICE ROAD
MATHEW DAM
ISLAND
UPPER POOL
HOLT ISLAND
OAK ISLAND
FILLING GATES
EXCAVATED AREA
LETITE
McMASTER ISLAND
C A N A D A
DAM
OCEAN
EXISTING TRANSMISSION LINE
SERVICE ROAD
DAM
LOCK
DAM
NEW ISLAND
DAM
KEY MAP
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA I
LETITE PASSAGE
International Passamaquoddy Engineering Board
PLATE I-3

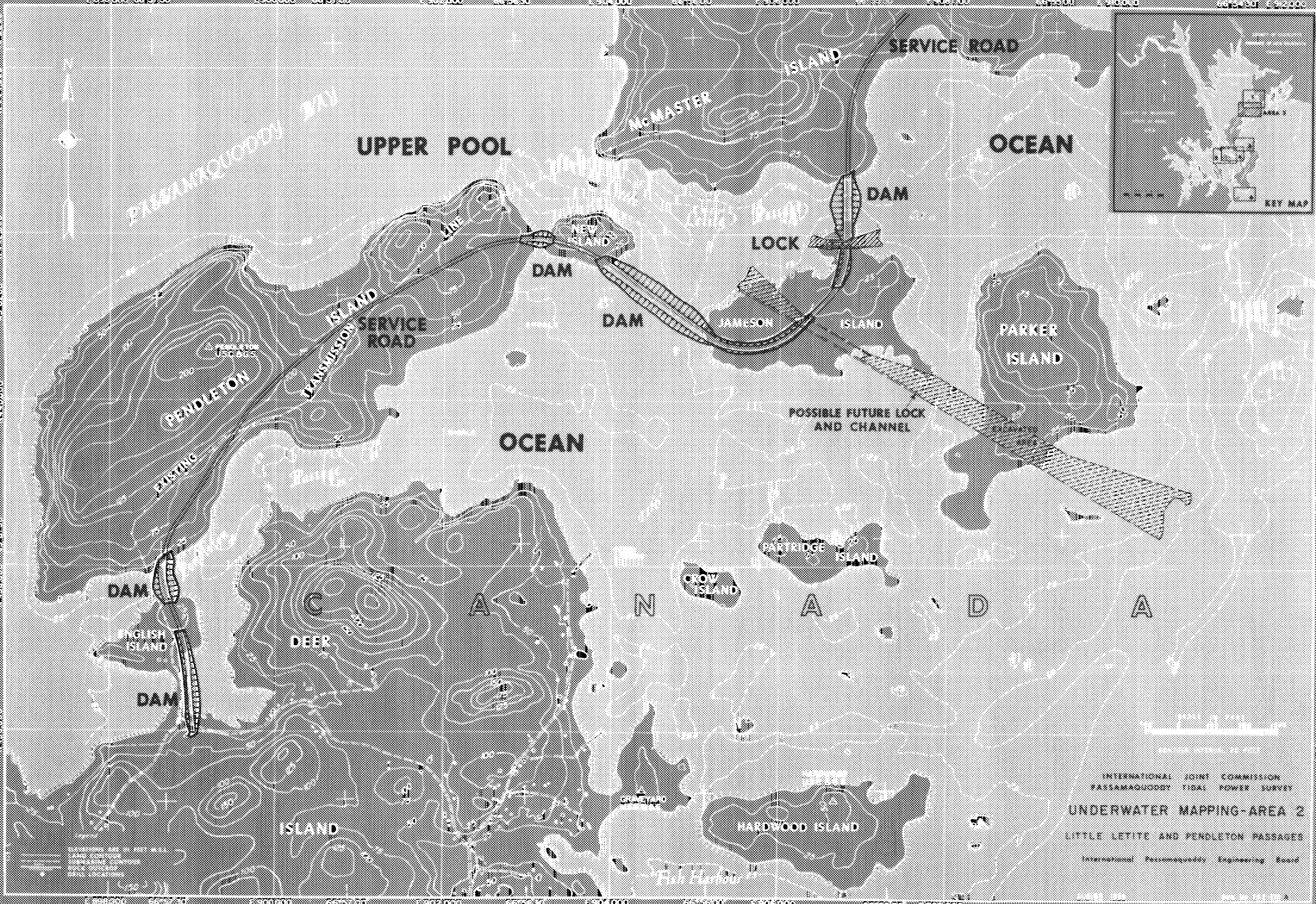

UPPER POOL
PASSAMAQUODDY BAY
OCEAN
McMASTER ISLAND
SERVICE ROAD
DAM
LOCK
NEW ISLAND
DAM
DAM
JAMESON ISLAND
PARKER ISLAND
POSSIBLE FUTURE LOCK AND CHANNEL
PENDLETON ISLAND
EXISTING TRANSMISSION LINE
SERVICE ROAD
OCEAN
DAM
ENGLISH ISLAND
DAM
C A N A D A
DEER ISLAND
PARTRIDGE ISLAND
CROW ISLAND
HARDWOOD ISLAND
Fish Harbour
KEY MAP
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA 2
LITTLE LETITE AND PENDLETON PASSAGES
International Passamaquoddy Engineering Board

PLATE I-4

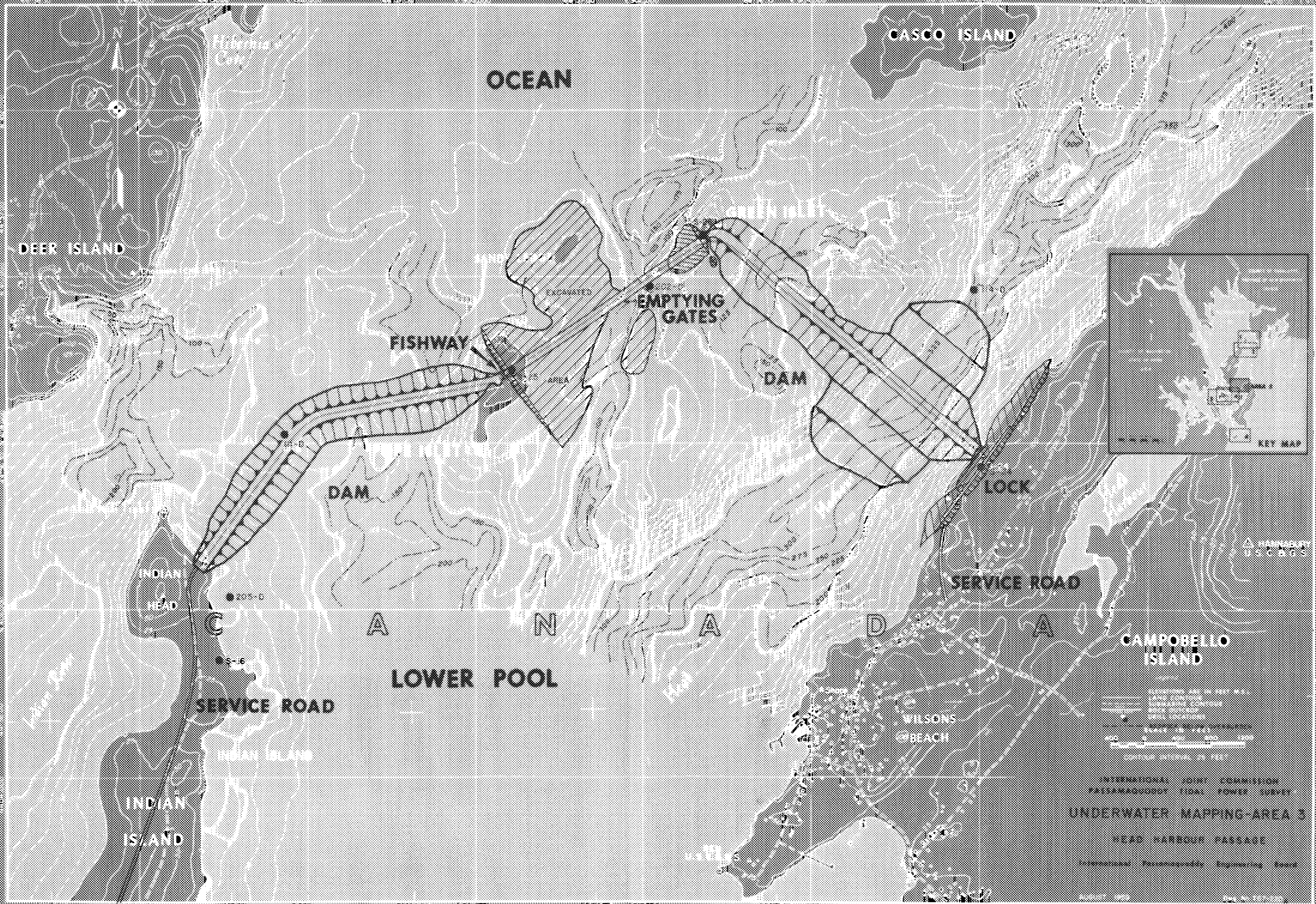

OCEAN
CASCO ISLAND
DEER ISLAND
FISHWAY
EMPTYING GATES
DAM
DAM
LOCK
SERVICE ROAD
INDIAN HEAD
C A N A D A
LOWER POOL
SERVICE ROAD
INDIAN ISLAND
CAMPOBELLO ISLAND
WILSONS BEACH
KEY MAP
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA 3
HEAD HARBOUR PASSAGE
International Passamaquoddy Engineering Board

PLATE I-5

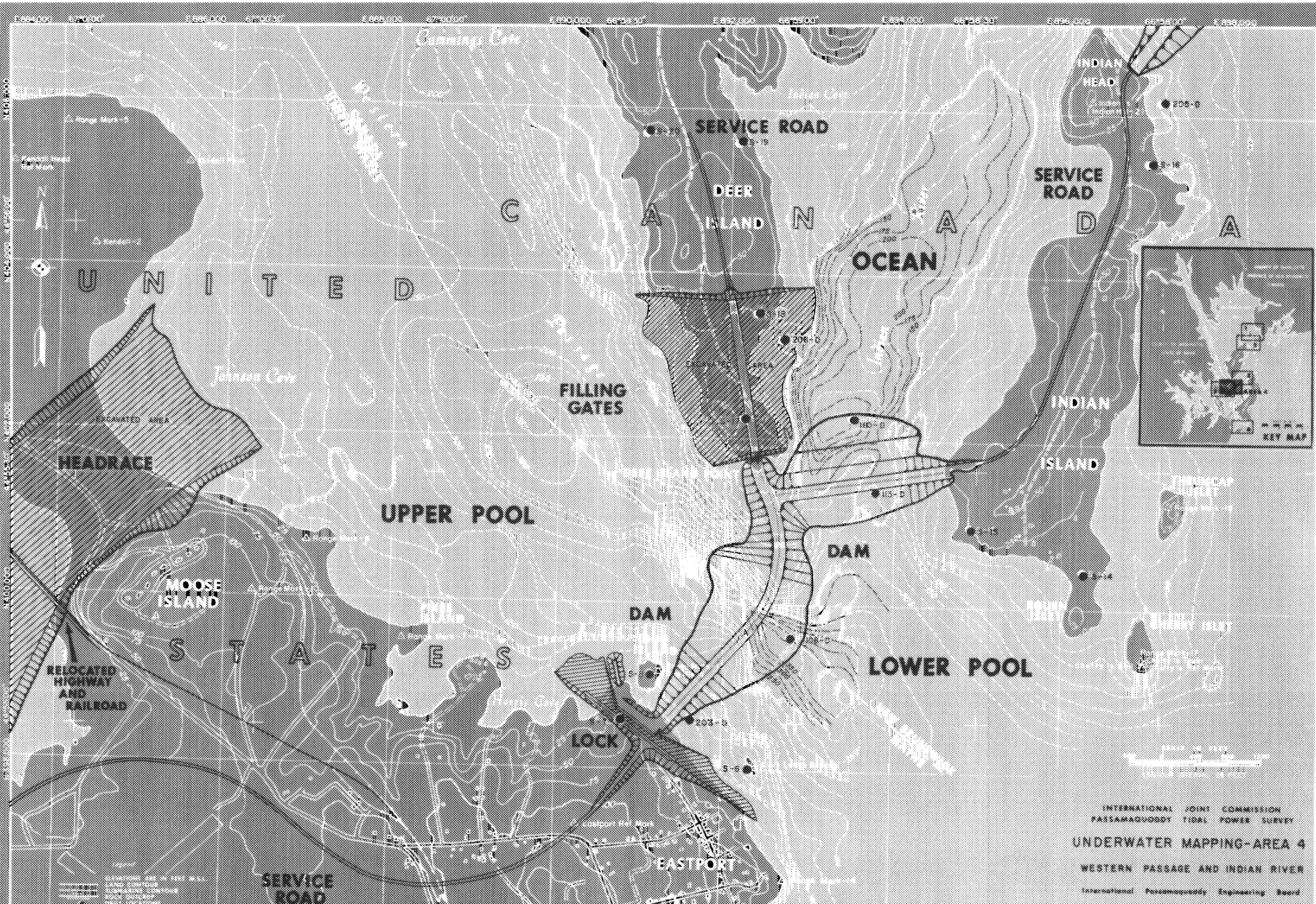
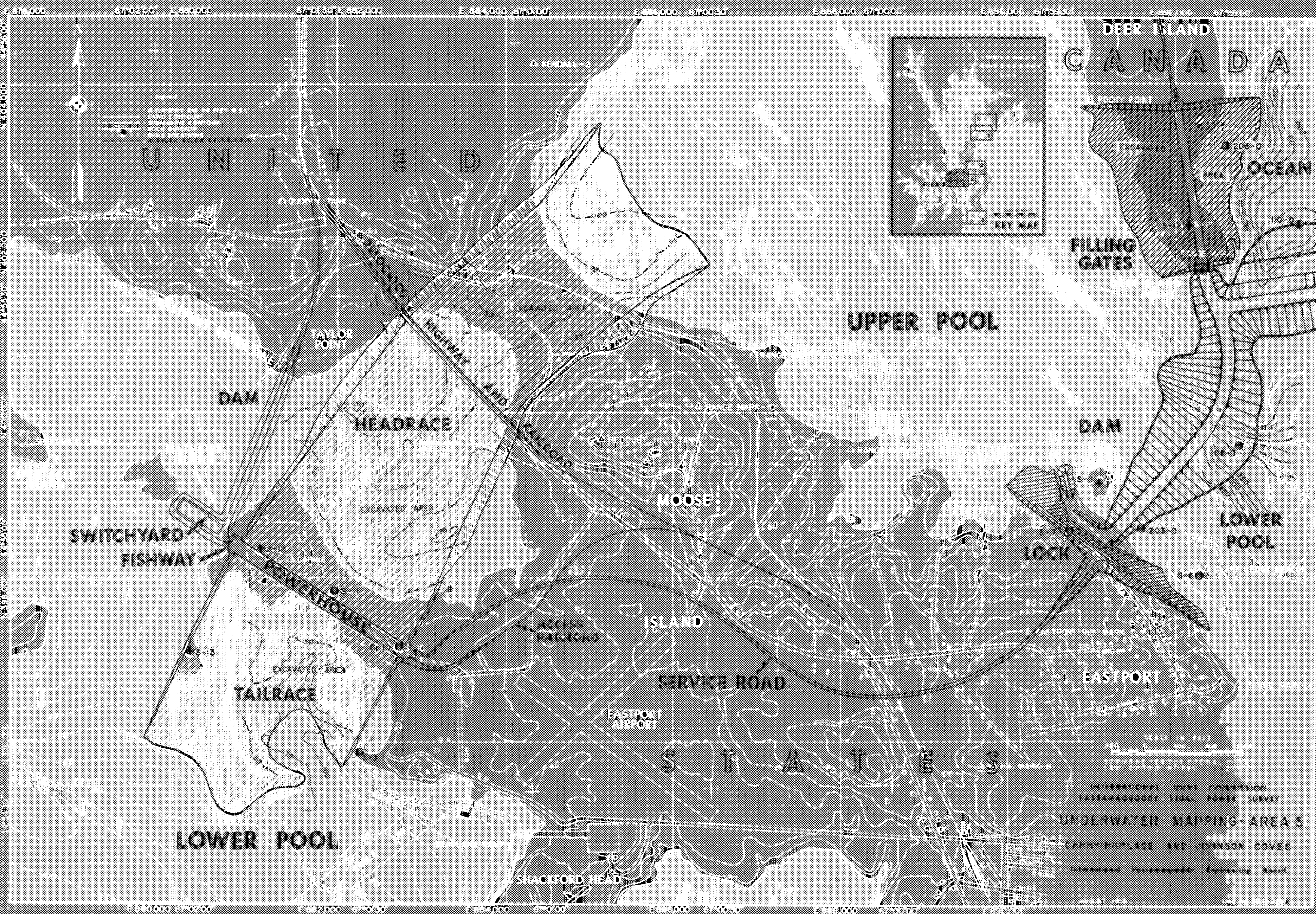
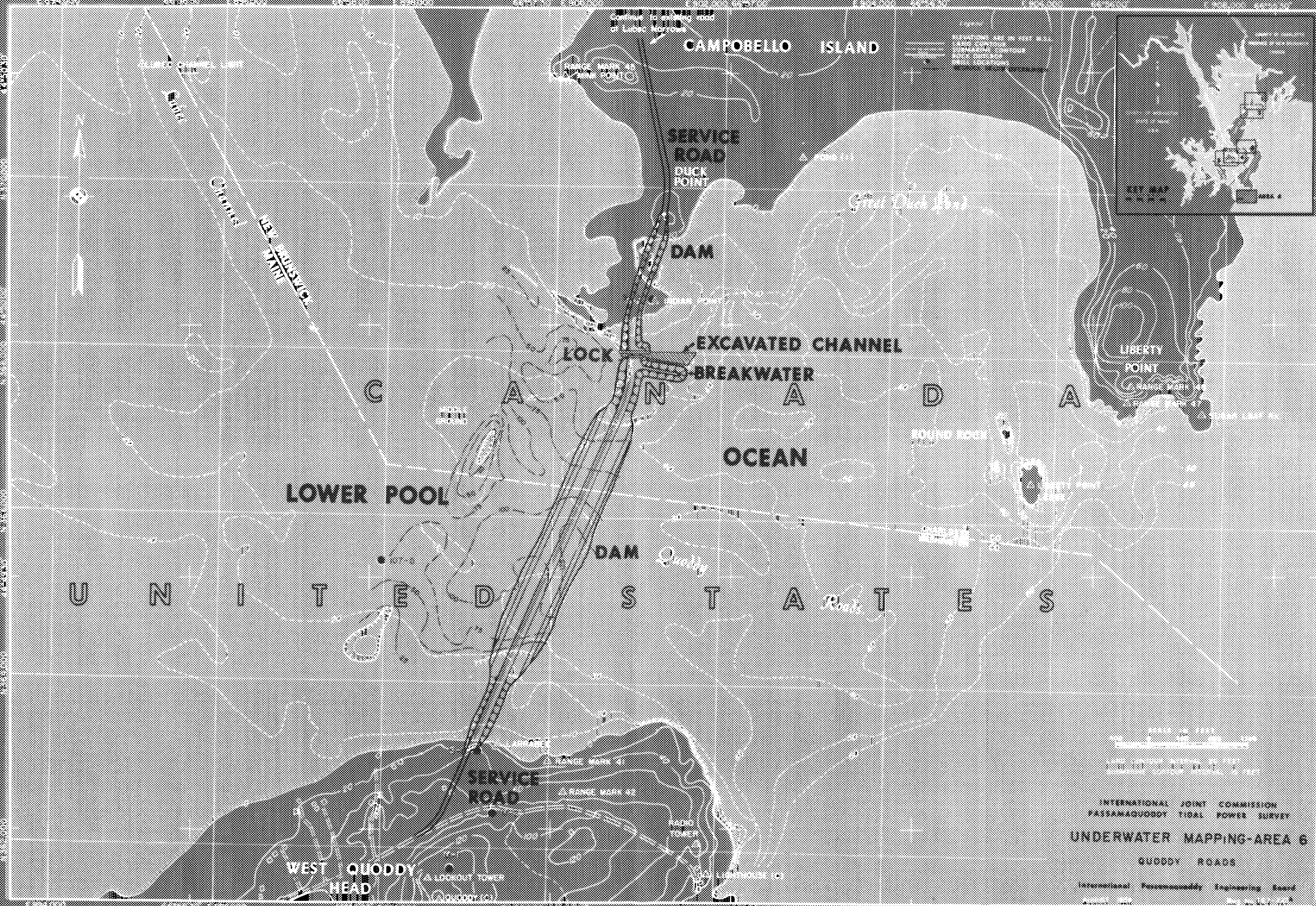

Cummings Cove
SERVICE ROAD
DEER ISLAND
C A N A D A
OCEAN
SERVICE ROAD
INDIAN HEAD
INDIAN ISLAND
U N I T E D S T A T E S
Johnson Cove
FILLING GATES
EXCAVATED AREA
HEADRACE
UPPER POOL
DAM
DAM
MOOSE ISLAND
RELOCATED HIGHWAY AND RAILROAD
LOCK
LOWER POOL
EASTPORT
SERVICE ROAD
KEY MAP
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA 4
WESTERN PASSAGE AND INDIAN RIVER
International Passamaquoddy Engineering Board

PLATE I-6



DEER ISLAND
CANADA
UNITED
STATES
KEY MAP
OCEAN
FILLING GATES
UPPER POOL
RELOCATED HIGHWAY AND RAILROAD
TAYLOR POINT
DAM
HEADRACE
EXCAVATED AREA
SWITCHYARD
FISHWAY
POWERHOUSE
MOOSE
ISLAND
ACCESS RAILROAD
SERVICE ROAD
EASTPORT AIRPORT
TAILRACE
LOCK
LOWER POOL
EASTPORT
SHACKFORD HEAD
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA 5
CARRYINGPLACE AND JOHNSON COVES
International Passamaquoddy Engineering Board



CAMPOBELLO ISLAND
SERVICE ROAD
DUCK POINT
Great Duck Pond
DAM
EXCAVATED CHANNEL
LOCK
BREAKWATER
C A N A D A
LIBERTY POINT
ROUND ROCK
OCEAN
LOWER POOL
NEW BRUNSWICK
MAINE
Channel
DAM
Quoddy Roads
U N I T E D S T A T E S
SERVICE ROAD
RADIO TOWER
WEST QUODDY HEAD
LOOKOUT TOWER
LIGHTHOUSE
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
UNDERWATER MAPPING-AREA 6
QUODDY ROADS
International Passamaquoddy Engineering Board

REPORT TO

INTERNATIONAL JOINT COMMISSION

ON

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 2

GEOLOGY, FOUNDATIONS, AND MATERIALS

BY

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

OTTAWA, ONTARIO
WASHINGTON, D. C.

OCTOBER 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 2

GEOLOGY, FOUNDATIONS, AND MATERIALS

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PLATES - (Continued)

PLATES - (Continued)

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 2

GEOLOGY, FOUNDATIONS, AND MATERIALS

2-01 PURPOSE

This appendix presents basic data on geology, foundation conditions, and construction materials which are essential to the studies made in connection with the proposed international Passamaquoddy tidal power project, and its auxiliary pumped-storage and river hydro power projects.

2-02 SCOPE

This appendix contains a summary of prior studies, existing data, and current investigations of the geology, foundation conditions, and availability of construction materials for the tidal power project, an auxiliary pumped-storage project, and an auxiliary river hydro project. Investigations, tests, and analyses performed for the present survey cost approximately $1,000,000. Field reconnaissance, subsurface explorations, and laboratory tests and office analyses are described and the applicable physical properties of the materials are presented. Application of the basic data developed in this appendix to project design is covered in the other appendices pertaining to specific structures. Location of tidal and auxiliary power sites is shown on plate 2-1.

2-03 PRIOR INVESTIGATIONS

a. General. During the initial phase of the current survey, a review was made of available data on geology, foundations, and materials applicable to the tidal project and its auxiliaries. General geologic data were obtained from publications of the Geological Survey of the United States Department of Interior, the Bureau of Geology and Topography of the Canadian Department of Mines and Resources, and the Maine State Highway Department. All known existing data developed during prior investigations of the sites considered have been carefully reviewed and used where applicable. The prior investigations are described in the following subparagraphs.

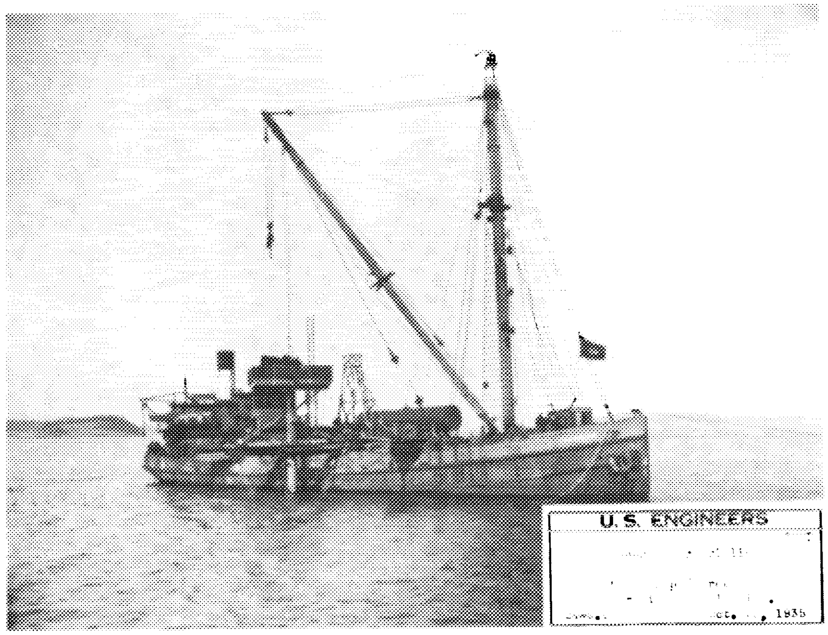
b. Studies by Cooper, 1926-28. Field investigation of foundation conditions and availability of construction materials by Dexter P. Cooper during the 1920's for an international Passamaquoddy tidal power project were preliminary in scope and apparently made without assistance of a geologist. Information developed was limited to that available from surface observations and inspection of rock from only a few core borings. Foundation exploration consisted of numerous wash borings and a few diamond drill holes on land at or near prospective structure sites. No subsurface explorations were conducted specifically for investigation of sources of construction materials.

c. Studies by U.S. Army Corps of Engineers, 1935-37.

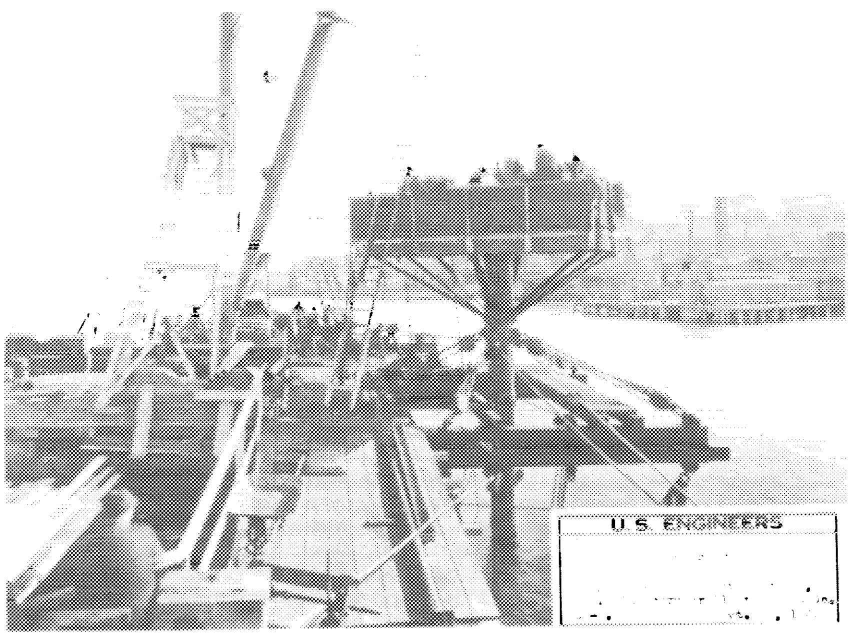
(1) General. In 1935 and the early part of 1936, the U.S. Army Corps of Engineers started construction of a single-pool tidal project entirely within the United States. Investigations and design studies for the entire project were undertaken concurrently in four divisions as follows:

Division I:	Eastport and Lubec rockfill dams, filling gates, and navigation lock.
Division II:	Powerhouse, headrace and tailrace, bridges at Carryingplace Cove, and dams at Pleasant Point and Carlow Island.
Division III:	Auxiliary pumped-storage plant and reservoir at Haycock Harbor, approximately eight miles southwest from Lubec, Maine.
Division IV:	Auxiliary pumped-storage plant and reservoir near Calais, approximately 20 miles northwest from Eastport, Maine.

(2) Field Exploration. A comprehensive program of field investigations was initiated in 1935 under the guidance of a staff geologist. Also, a consulting geologist examined a great deal of the work as it was in progress. Subsurface explorations were performed by both contract and hired labor operations. Contract drilling included 297 borings. Project forces made approximately 2,000 explorations of which the most important were 36 deep water borings in the Eastport-Lubec area. Photographs 2-1 and 2-2 show the general



Photograph 2-1 General View of Plant for Deep Water Drilling - 1935.



Photograph 2-2 Drilling Platform for Deep Water Drilling - 1935

view of the plant for deep water drilling and the drilling platform used in 1935. Samples of overburden consisted of 4-7/8-in. diameter undisturbed samples of clayey materials in foundation areas and 2-in. drive samples of granular materials; in bedrock 1-1/8-in. diameter cores were obtained. Representative samples of remolded materials were obtained from auger borings and test pits. Extent of the exploratory program is indicated in the following tabulation of type and number of explorations in each of the four divisions enumerated above.

Div.	Contract borings	Hired Labor Explorations					
		Deep water	Shallow water	Land borings	Jet probings	Test pits	Auger borings
I	39	36	3	24	390	19	
II	58				590	19	136
III	123				201	333	27
IV	77					224	
Totals	297	36	3	24	1181	595	163

(3) Laboratory Investigations. A soils laboratory was established in Eastport, Maine, for identification and classification of soils in foundation areas and of soils proposed for use in embankments, and for development of their engineering properties for design purposes. In addition, a concrete laboratory was established for investigation of aggregates from local sources and for design of concrete mixtures for project requirements.

(4) Records and Reports. Records of all explorations, location maps, and cross sections were prepared and are available for the current investigations. Construction work on the project was terminated in August 1936 and only limited funds and personnel remained for preparing final reports and maintaining the dams. Fairly complete reports were prepared by the consulting geologist, Irving B. Crosby, on the Calais reservoir, the Haycock Harbor reservoir, the lock site on Treat Island, and the powerhouse at Carryingplace Cove. Very general reports were made by project personnel on the Eastport and Lubec dam sites, the Treat Island filling gate site, the Shackford Head quarry site for concrete aggregate, the Treat Island quarry for embankment material, and the Johnson Bay soil borrow area. A special report pertaining to granite for construction was made by E. H. Hopson. Complete final reports on investigations of soils and concrete aggregates were prepared, and these have been particularly helpful in the present survey.

d. Fathometric Survey, 1951. The fathometric survey conducted by the Water Resources Division of the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers in 1951 produced valuable data on extent of subaqueous overburden materials. The data have been used in conjunction with other and more recent subsurface explorations to interpret foundation conditions. This survey is described in more detail in appendix 1, "Topography and Underwater Mapping."

e. Studies by International Saint John River Engineering Board, 1952. Investigation of geology, foundation conditions, and construction materials for a proposed dam at Rankin Rapids on the upper Saint John River were conducted by the International Saint John River Engineering Board in 1952. Information from this investigation has been used with only minor additional field exploration in the current survey of the Rankin Rapids site as one of the possible locations for an auxiliary river hydro project.

2-04 TIDAL POWER PROJECT

a. General. The investigations pertaining to regional and site geology, foundation conditions, and construction materials for the tidal power project were started early during the current survey. Preliminary findings influenced the study described in appendix 5, "Selection of Plan of Development" to determine the tidal project layout for which a complete cost estimate was prepared. The layout selected for this purpose is shown on plate 2-2. Maps of each of the areas in which tidal project structures would be built are shown in appendix 1, "Topography and Underwater Mapping."

b. Existing Data. Existing data on local conditions have been gathered by Dexter P. Cooper, by the U.S. Army Corps of Engineers and by others as previously described. All existing data were used to conserve field investigations of the current survey. Sufficient studies were made, however, to assure the validity of any existing data incorporated in this appendix.

c. Regional Geology.

(1) General. The Passamaquoddy area is part of the Appalachian province which includes a region of mountainous and coastal lands and waters extending from Alabama to Newfoundland. The project area has been subjected to numerous crustal and mountain building movements and has been altered by the intrusion of large masses of igneous rock and extensive flows of volcanic rocks. The older formations were buried

deeply and greatly metamorphosed. After Devonian times this area was essentially a land mass sloping gently seaward. The project area was then uplifted producing deep valleys and steeply dipping tributaries. In the more recent Pleistocene time, the glacial ice advanced from the northwest over this surface. The area was depressed by the weight of the ice and its load of glacial sediments. At the same time, the land was smoothed and beveled as the existing mantle of overburden and weathered rock was incorporated into the advancing ice sheet and moved by it. This movement also changed the drainage system existing at the time. The melting of the ice unloaded the glaciated areas which then rose to regain partially the levels prevailing before glacial times. The passages around the islands in the project area are the old stream valleys, now partly drowned, and the numerous islands themselves are the higher parts of the pre-glacial land mass.

Erosion is now cutting through the thin mantle of glacial sediments deposited over parts of the land surface. The exposed rock in the land areas is weathering, and wave action and stream erosion are further modifying the land areas. Several areas of outwash sand and gravel were deposited by the glaciers. The principal deposits along the project coastal area are at Lubec, on Campobello Island between Friar and Herring Bays, along the northeast shore of Moose Island, the cove areas on the southwest shores of Deer Island, along the St. Croix River at Sand Point, New Brunswick, and the Bethel terrace area, east of the Digdeguash River, at the north end of Passamaquoddy Bay. The locations named above are shown on plate 2-3.

It appears that glacial terminal moraines dammed the passage at Lubec Narrows and Friar Roads, crossing Moose Island to the vicinity of Kendall Head and dammed the Western Passage across to the Cummings Cove area. As the glacier melted deep deposits of marine clay and silt were deposited behind this barrier in Cobscook Bay and over much of Passamaquoddy Bay.

(2) <u>Overburden</u>. Overburden in the project area consists of unconsolidated surficial deposits of glacial origin, of more recent weathered granular materials, and of peat. The glacial deposits are composed of a thin and discontinuous mantle of till, outwash materials in terraces and beaches, and silts and clays deposited in water. Sand, gravel, and talus weathered from rock outcrops are being transported to form post-glacial beaches, underwater granular deposits and stream deposits. Peat occurs in many of the low land areas.

(3) <u>Bedrock</u>. Bedrock in the project area includes sedimentary and igneous rocks of Silurian and Devonian ages. The various formations occurring in the project vicinity are summarized as follows:

(a) The oldest rock known is the Quoddy shale consisting of discontinuous beds of blue to purplish shale separated by bodies of intrusive rock. The formation is quite thick, evenbedded, fine-grained and highly quartzose with occasional fissile beds. This shale has been subjected to considerable metamorphism which has altered some of it near the igneous rocks until some schistosity has occurred. The large amount of volcanic rock associated with the shale strongly indicates concurrent deposition. The Quoddy shale has sufficient strength to support any of the structures proposed for the tidal power project, and is sufficiently durable for use in the tidal dams. The shale outcrops in the Lubec and West Quoddy Roads area in the United States and in the southern part of Campobello Island in Canada, and was encountered in subsurface exploration drill holes in the tidal project area south of Deer Island.

(b) The Dennys, Edmunds, and Pembroke formations occur above the Quoddy shale and are located along the west side of Cobscook Bay and were named from the towns of Dennysville, Edmunds, and Pembroke where they outcrop. These formations are composed mainly of volcanic rocks with a few interbedded sedimentary rocks. They do not occur in the proposed structure foundation area and have not been considered as a source of materials.

(c) The Eastport formation is the upper, or youngest, part of the rocks of Silurian age and outcrops mainly in a narrow belt extending from Eastport several miles to the northwest. This formation is composed of igneous rhyolite flows, rhyolite tuffs, basalt, some diabase with associated beds of shale, and minor beds of limestone and conglomerate.

(d) The youngest rock in the area is the Perry formation of Devonian age composed of cemented red and brown sandstone and conglomerate, with minor amount of red shale and interbedded flows of basalt and diabase. This formation outcrops north of Perry, Maine; in the area of St. Andrews, New Brunswick; on several islands in the vicinity of Letite and Head Harbour Passages; and was encountered in drill holes in Passamaquoddy Bay.

(e) Deer Island, the upper part of Campobello Island, and the Letite Passage area are underlain mainly by igneous rocks of volcanic origin of Silurian age consisting of a complex mixture of acidic rhyolites and tuffs, intermediate andesites and diorites, and basic basalts and fine-grained diabase. Some interbedded sedimentary rocks occur with the igneous rocks which have been metamorphosed locally to slates, argillites, schists and quartzites. Several intrusive dikes and masses of coarse-grained diabase and gabbro of the same age occur with the volcanics. Granite occurs along the St. Croix River and outcrops to the north and west of Passamaquoddy Bay. All of these rocks have sufficient strength to support any of the structures of the proposed tidal power project. Considerable faulting has taken place in the area and known, relatively inactive faults extend through Head Harbour and Western Passages. Numerous volcanic flows, sills, dikes, and masses of intrusive origin have locally tilted and deformed the original rock formations. Mountain building forces have exerted pressure on the rocks over large areas. As a result of these many movements the older rocks are dipping from a few degrees to vertical with lesser dips occurring in the youngest rocks.

(4) Earthquakes. The Passamaquoddy Bay area has been relatively free of earthquakes during recent time. Minor tremors have occurred from time to time as the rocks adjust to differences in internal stresses. These small adjustments would occur mainly along the faults under the deepest portions of Head Harbour and Western Passages but would not be sufficient to affect adversely the stability of the rockfill dams at these locations. Apparently recovery from compression of the earth surface due to glaciation is essentially completed in the tidal project area.

(5) Economic Geology. The mineral resources of the project area are composed of small amounts of lead, zinc, and copper, none of which appear profitable for commercial development. Numerous peat areas occur but these have not been exploited. Sources for road building materials such as sand, gravel, and crushed rock are developed as needed.

d. Field Exploration.

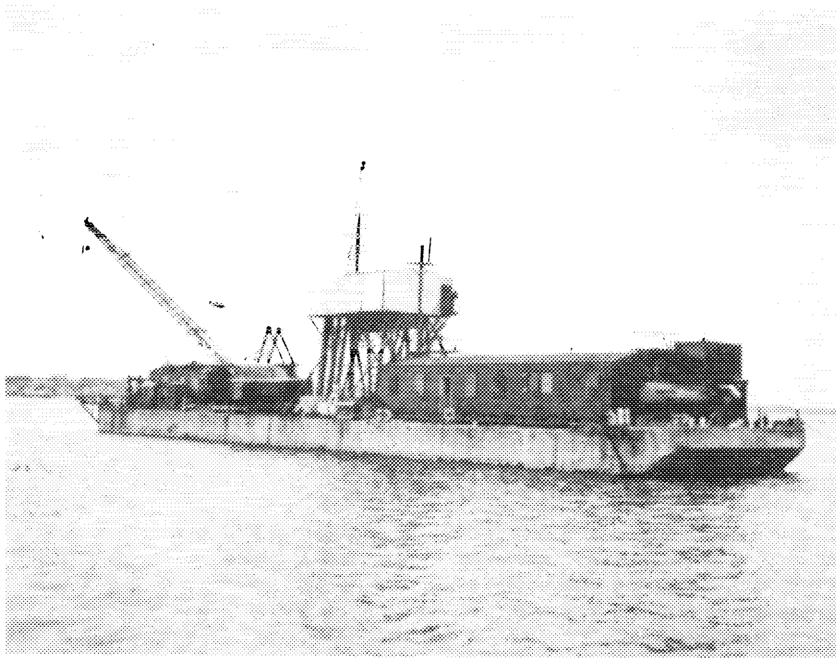
(1) Reconnaissance. Considerable time was spent in the early stages of the survey in making a reconnaissance of all potential structure areas in order to become acquainted with the type of rocks to be encountered, the amount of overburden, and configuration of the shore and underwater areas. This reconnaissance was extended to include all prospective areas for obtaining construction materials with particular emphasis on sources of sand and aggregates for concrete, and of large stones for embankment slope protection against wave action. As the design studies progressed to the point where the project arrangement has been selected and location of the structures was fairly firm, a more detailed field study was undertaken at the structure sites to correlate the rock exposures with the cores drilled in these areas to determine the nature and condition of the

rock, the type of fractures, contacts between different types of rock, and any other data pertinent to structure foundation design. The area prospected and the location of principal sources of construction materials considered for project design are shown on plate 2-3.

(2) Sonic Survey. One of the principal phases of the current site investigations consisted of a sonic survey to explore underwater foundation conditions. Presentation and discussion of this investigation have been made in appendix 1, "Topography and Underwater Mapping."

(3) Subaqueous Drilling. In order to determine the type of sediments in the deeper passages and shallow water areas where structures were planned, a contract was awarded to Brown and Root Marine Operators, Inc., of Houston, Texas, for drilling and sampling in 15 deep water holes and six shallow water holes. The general location of these explorations is shown on plate 2-2. Of the 15 deep water holes 13 were drilled 20 feet into rock and two were stopped after penetrating about 50 feet of granular material which was considered sufficient for foundation design. The deep water work included a total of 888.7 feet of overburden penetration from which 115 undisturbed samples, 5 inches in diameter, were obtained, and 261.1 feet of rock core drilling. The shallow water drilling consisted of 91.9 feet of overburden drilling and 159.5 feet of rock coring principally for investigation of foundation conditions for proposed gates and navigation locks. The subaqueous drilling program was conducted with conspicous success in spite of the difficult operational problems presented by great water depths, the rapidly changing depths due to the large tide range, and the rapid tidal currents. The undisturbed samples of silty clay from the foundation areas investigated for tidal dams were obtained in excellent condition for laboratory tests and analyses. Specific locations of explorations in areas finally selected for tidal power project structures are presented in appendix 1 on maps of proposed structure areas. Boring records for the 1957 subaqueous drilling program are shown on plate 2-4. The results obtained from this drilling program were used to locate the best locations for the tidal dams and to aid in the interpretation of the sonic surveys. Photographs 2-3 and 2-4 show the drill barge used by the contractor and a view of the elevated deck used for drilling operations.

(4) Land Drilling. A contract was awarded to Boyles Brothers, Ltd., of Moncton, New Brunswick, for drilling and sampling in 28 holes on land and in prospective structure areas above low tide, and in 15 holes in four areas to investigate sources of rock suitable



Photograph 2-3 General View of Plant for Deep Water Drilling - 1957.

Photograph 2-4 Drilling Platform for Deep Water Drilling - 1957.

for concrete aggregate and large stones for embankment slope protection. The general location of these borings is shown on plate 2-2. Records of exploration are shown on plates 2-5 through 2-8, inclusive, with more detailed location of quarry explorations shown on plates 2-6, 2-7, and 2-8.

(5) Power Auger Borings. Reconnaissance for construction materials in the project vicinity indicated several prospective sources of natural concrete aggregates and embankment materials. In areas considered most promising for development, subsurface explorations were performed under contract by J. R. Cianchette, Pittsfield, Maine, using a bucket-type power earth-boring auger. Auger holes, 30 inches in diameter, were made in several areas with depth of penetration varying from 6 to 57 feet. For the areas where substantial quantities of suitable materials were discovered, location of explorations and logs of borings are shown on plates 2-9, 2-10, 2-11, and 2-12. Exploration was started in a few other areas but was stopped when materials not suitable for project use were disclosed or where the shallow depths of suitable materials indicated an insufficient quantity.

(6) Miscellaneous Explorations. In addition to the principal exploration programs described above, a considerable amount of subsurface investigation was made by use of hand auger boring and trenching in existing exposures. These secondary explorations were conducted primarily to determine extent of materials discovered by reconnaissance or to extend the findings made by more expensive methods. The locations and boring logs have been included on plates showing major explorations. Other explorations which were only preliminary in nature and used as part of the reconnaissance operations have not been separately presented but information obtained from them has been used in the overall materials evaluation. Explorations in the Carryingplace Cove area which were made by the U.S. Army Corps of Engineers in 1935 have been used for the subsurface investigations of the current survey with only a few additional auger borings to obtain fresh samples for analysis. Location of these explorations and logs of borings made in 1957 are shown on plate 2-13. Core-boring records for the explorations made in 1935 are shown on plates 2-14, 2-15, and 2-16.

e. Laboratory Tests and Analyses of Foundation Soils.

(1) Field Laboratory. During initial planning for this survey, consideration was given to testing foundation soils in an existing laboratory of the U.S. Army Corps of Engineers. This would,

however, entail shipping the samples over considerable distances during which their properties could change due to shaking, freezing, and other effects. In order to assure accurate test results, it was decided to establish a laboratory in the field office at Eastport, Maine. Equipment was purchased and installed for performing all usual identification and soil classification tests. Also included were an unconfined compression device, two double-unit consolidation machines for samples 4-1/4 inches in diameter, two direct-shear machines for 3-inch by 3-inch samples, and a double unit triaxial-shear machine for samples of 1.4 and 2.8 inches in diameter. The laboratory testing was performed under contract by Greer Engineering Associates of Montclair, New Jersey. All samples were classified in accordance with the "Unified Soil Classification System" of the U.S. Army Corps of Engineers. Laboratory test methods followed closely the procedures set forth in the American Society of Testing Materials specifications for determination of moisture content, unit dry weight, particle size gradation, specific gravity, and Atterberg limits. Direct-shear tests were performed in accordance with instructions contained in the publication, "Soil Testing for Engineers" by T. William Lambe. Procedures for performing consolidation, triaxial compression, and unconfined compression tests were essentially those contained in Harvard University Publication No. 268, "Notes on Soil Testing for Engineering Purposes" by A. Casagrande and R. E. Fadum.

(2) Test Program. As the deep-water drilling progressed and as samples were delivered to the laboratory, a careful study of the records of exploratory operations was made, each sample was examined, and routine classification tests were performed. Subsequently, particular samples were selected which represented the areas investigated, depths explored, and range of soil classifications encountered. Tests were made on these selected samples to determine shear strength and consolidation characteristics for analyses of stability and settlement of foundations of project structures. A total of 115 undisturbed samples of silty clay were examined and tested. Also, identification and classification tests were made of granular materials encountered in foundation explorations or in prospective sources of construction materials.

(3) Analyses of Test Results. All test results were examined to ascertain consistency and spread of data and to assess the reliability of individual tests. Correlations of data have been studied on the basis of areas of occurrence, depth of penetration, relative elevations, and with respect to classification ranges. To determine typical properties, the test results were grouped on a selective basis with emphasis on data of greatest consistency and reliability.

(4) Engineering Properties of Soils. Results of individual laboratory tests of foundation clays are presented on plates 2-17 through 2-32, inclusive. Engineering properties of typical foundation soils representative of areas investigated are shown on plates 2-33, 2-34, and 2-35. Application of basic data is discussed in other appendices pertaining to specific structures. However, significant conclusions of the investigations of engineering properties of the foundation soils in the project area are summarized below:

(a) Where essentially granular deposits occur, the materials are generally compact gravels and sands of good bearing quality.

(b) Non-granular deposits are predominantly silty clays which are somewhat more dense than would result from full consolidation under the existing overburden load but would undergo long-duration consolidation under added load of prospective structures. An exception to this general conclusion is noted for the clays in Passamaquoddy Bay and in Indian River which are only partially consolidated under existing overburden load.

(c) Shear strength of the foundation clays varies considerably over the project area. Strongest materials were found in the Quoddy Roads area; weakest materials were found in the middle of Passamaquoddy Bay and in Indian River.

f. Site Geology and Structure Foundations.

(1) General. Discussion of site geology and existing foundation conditions is presented in the following paragraphs for the six areas of the overall project structure layout presented in the series of plates in appendix 1, "Topography and Underwater Mapping." The locations of the drill holes referred to in the following paragraphs are shown in detail on the plates in appendix 1. Geologic profiles in proposed structure areas are shown on plates 2-36, 2-37, and 2-38. Overburden was found in all deep and shallow water drill holes with one exception. Apparently overburden covers most of the ocean floor in the project area. Its thickness and

character are dependent on the amount and type of sediment which was deposited during glacial times, the irregularities of the bedrock surface, the strength of the tidal currents sweeping the ocean bottom and the amount and type of material weathered and eroded from the existing land masses. Investigations and analyses indicated conclusively that bedrock is adequate for foundation of all concrete structures proposed. For the proposed tidal dams, however, the existing foundation conditions vary as described below. Analysis of embankment foundations conditions with respect to design of the tidal dams is presented in appendix 9, "Tidal Dams and Cofferdams."

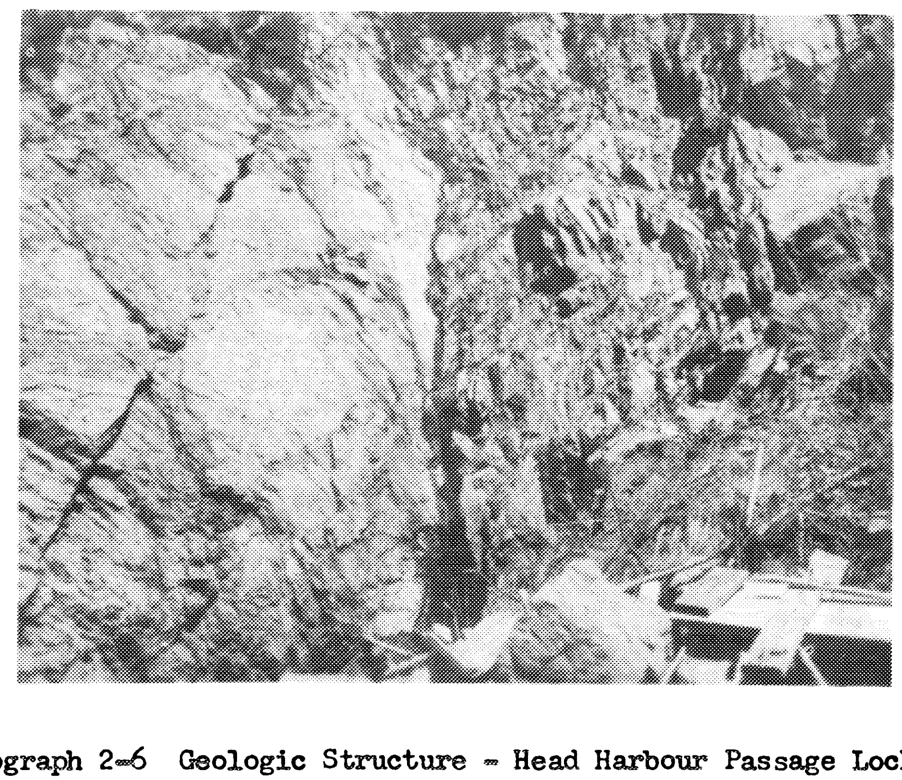
(2) Area 1 - Letite Passage.

(a) Tidal Dams. The principal dam in area 1 would be between McMaster Island and Dry Ledge, and would be founded on rhyolite, basalt, and diabase except where granular overburden exists. The maximum depth of the passage varies from 150 to 190 feet across the width of the dam. The existing bottom slopes are relatively flat except in the deepest part of the channel where the slopes steepen to as much as 1 on 3. Some granular sediments occur in irregularities in the bedrock surface. The 1951 sonic survey indicated as much as 75 feet of sediment in the deepest portion of the channel which is probably mostly granular. Very little settlement is anticipated in this overburden. A small dam would be required to close minor passages which extend only into tide range between the intake gate locations and the Canadian mainland. Sandy beach deposits occur in the irregularites of the rock coastline in this area. A typical example is illustrated in photograph 2-5 showing the beach on the north side of McMaster Island just west of location of drill hole S-27.

(b) Intake Gates. Foundation rock for the proposed filling gates at Letite Passage consists of basalt with some coarser-grained tough dense diabase as shown in the core from the land drill holes S-28 and S-29 and in shallow water drill hole 201-D. The surface rocks on Dry Ledge show some vertical schistosity which trends in a N23°E direction. Seven feet of granular material occurred in drill hole 201-D and it appears that considerable overburden exists on the bottom in this part of the channel, especially in the area between drill hole 201-D and Thum Cap Island. The thickness of this material will vary according to the irregularities in the bedrock.

(c) Navigation Lock. One location of a navigation lock serving the Letite Area was considered but since abandoned at the northeast side of McMaster Island near drill hole S-27. The core from drill hole S-27 was mainly a dark gray, siliceous, fine-grained

Photograph 2-5 Geologic Structure - Shore Deposits on McMaster Island.



Photograph 2-6 Geologic Structure - Head Harbour Passage Lock Site.

Dwg. No. TG7-170
October 1959

rhyolite. Some high-angle joints showing movement and numerous small, healed fractures occur in the rock. An occasional shear plane would probably be encountered in excavation at this location. This siliceous rhyolite is difficult to drill and since it is brittle it will tend to break into small angular pieces when blasted.

(3) Area 2 - Little Letite and Pendleton Passages.

(a) Tidal Dams. The proposed dam between McMaster and Jameson Islands, crossing Little Letite Passage, would rest on an argillite on the Jameson Island abutment. The argillite has been metamorphosed in some areas until it has schist-like qualities and contains some quartzose beds. These rocks strike N25°E and dip 66° southeast. The rock is dense, tough, and tightly cemented, and weathers into irregular blocks. The abutment location on McMaster Island is in an area of massive medium-grained diabase. The bottom slope is about 1 on 6 on the Jameson side of the channel and about 1 on 4 on the McMaster side which indicates that considerable granular material has been washed from the islands into the channel which reaches a maximum depth of 52 feet below mean sea level. Some beach-type material can be seen on the bottom in shallow water at low tide. This material would probably settle very little due to the weight of the proposed dam. A longer dam is proposed between New Island and Jameson, south of Little Letite Passage, where the maximum depth of the channel reaches 53 feet below mean sea level along the center-line. The bottom topography is irregular which indicates that bed-rock will be found on the bottom of this channel under parts of the proposed dam with granular materials occurring in depressions in the bedrock. Bedrock on the Jameson abutment is a dense rhyolite; on New Island basalts and some diabase are found. Very little settlement should occur under a dam in this location. At Pendleton Passage (Doyles Crossing) a short dam is proposed where the maximum depth of the channel is about 25 feet. Bedrock is composed of basalt with some diabase at the abutment on Pendleton Island, and of an argillite with fissile qualities which are vertical and trend N25°E on the Deer Island abutment.

(b) Navigation Locks. A location for a small boat lock in the Little Letite Passage area has been selected across the north end of Jameson Island near the south abutment of the proposed dam between McMaster and Jameson Islands. Bedrock is similar to the rock at the south abutment of this dam. This rock is adequate to support the lock structure. Since the axis of the lock is nearly normal to the strike of the beds, overbreak from the steeply inclined beds would be minimized. A large lock for possible future traffic was also studied, cutting through Jameson and Parker Islands. This route was not examined in detail but is in an area where the bedrock is massive rhyolite on Jameson Island and steeply dipping rhyolite and argillite on Parker Island. Very little overburden occurs on the islands although they are covered for the most part with dense woods. The rocks are not deeply weathered. Some beach deposits occur between the islands and at each end of the approaches to the lock some granular material occurs which has weathered from the land and washed into the ocean.

(4) Area 3-- Head Harbour Passage.

(a) Tidal Dams. Two dams are proposed for the Head Harbour Passage area, a major dam between Green and Campobello Islands and a smaller dam between Indian and Pope Islands. Geologic evidence indicates that the pre-glacial bedrock channel in Head Harbour Passage is about 400 feet below sea level. This depth was indicated by the 1951 sonic survey but the Fairchild sonic survey in 1957 failed to penetrate the granular material in this passage. The Campobello Island abutment of the Green to Campobello Island dam was explored by drill hole S-24 which encountered schist. Considerable basalt is also found in this abutment area. Some shear zones occur which are the results of the faulting in Head Harbour Passage.

The rocks at the Green Island abutment area consist of dense medium- to coarse-grained diorite. Conglomerate occurs under the overburden throughout much of the channel area. Two areas of overburden exist at this crossing. Drill hole 114-D was drilled along the west side of the pre-glacial channel and north of the proposed dam crossing. The channel bottom was at a depth of 316 feet where granular material was encountered for 18 feet to -334 m.s.l., after which clay was encountered. This clay appears to reach a thickness of at least 65 feet in the deeper portion of the pre-glacial channel east of drill hole 114-D. The granular material covering the clay has been weathered from the steep western side of Campobello Island and transported by tidal currents to deeper parts of the passage. The slope of this material is about 1 on 3 for a distance of 600 to 700 feet west of the island. It then flattens considerably for another 600 to 700 feet before the bottom reaches its lowest level with the result that the deepest part of the existing bottom has shifted a short distance west of the deeper old pre-glacial channel, and that the granular material is thicker over the clay near the eastern or Campobello side of the pre-glacial channel. Presence of clay in the foundation area would require flattening of embankment slopes to spread the load of the tidal dam sufficiently to ensure foundation stability.

Photograph 2-7 Geologic Structure - Shore Deposits on Campobello Island.

Photograph 2-8 Geologic Structure - Quoddy Roads Shale with Basalt Capping.

The second area of overburden exists east of Green Islet where the 1957 Fairchild sonic survey indicated overburden reaching a width of about 500 feet and a maximum depth of over 40 feet. No drilling was performed in this local area to verify extent of overburden materials. However, overall analysis of existing conditions indicates somewhat greater lateral extent of overburden than shown by the Fairchild sonic survey. The proposed dam between Indian Island and Pope Islet would rest on bedrock and granular material both of which are entirely adequate to support this structure. Granular deposits extend out into the channel from both islands to unknown depths and probably surround irregularities in the bedrock. Geologic structure of shore deposits on Campobello Island are shown in photograph 2-7. Drill hole 111-D located bedrock on the bottom of this channel and the sonic survey did not show any penetration into the bottom at this location. Near the north end of Indian Island drill hole S-16 on land, shallow water drill hole 205-D, and deep water drill hole 111-D were drilled in dense, fine-grained basalt. Drill hole S-25 was located on Pope Islet in a quartzite area surrounded by rhyolite flows.

(b) Emptying Gates. Land drill holes S-25 and S-26, and shallow water drill hole 202-D, were drilled in the area proposed for emptying gates between Pope and Green Islets. Quartzite, diorite, and basalt were the main types of rock found in the cores from these three holes. In addition, some rhyolite flow rock occurs at the surface on Pope Islet and in the Sandy Ledge area. These rocks are sound and entirely adequate to support the gates. Considerable granular material has been weathered from these three islands and this material has been washed over portions of the ocean bottom. Sandy Ledge was named from the sandy granular material which forms a beach along the south side of the western portion of the ledge with the top of this beach extending about six feet above sea level. Above low tide level this granular material has an average slope of about 1 on 10, and below low tide, in areas of the tidal currents, the natural slope is about 1 on 3.5. Excavation for the gates would encounter a considerable amount of this granular material in varying thicknesses. The granular material smooths out the bottom areas between the rock exposures.

(c) Navigation Lock. The rock outcropping along the shore line of Campobello Island in the vicinity of the proposed lock site rises nearly vertically to a height of about 40 feet along the alignment of the lock and approaches. The rock then rises inland on a steep slope until it reaches elevations of 80 to 100 feet above sea level. Land drill hole S-24 was located along the alignment of the proposed lock opposite the east end of the proposed tidal dam alignment between Green and Campobello Islands. Along the shore the rock consists of interbedded schist and basalt which has undergone considerable deformation as shown in photograph 2-6. A major fault system passes through Head Harbour Passage and the rock mass at the lock site has been tilted to the east with dips ranging from 65° to vertical and with the strike approximately N35°E paralleling the direction of Head Harbour Passage. This fault is not active and would not affect the lock, the foundation for which would be cut deeply into the east wall of the bedrock valley more than 2,000 feet from the main portion of the fault. Several shear zones have developed along the strike of the rocks and many healed fractures occur. Rock excavation should produce tabular pieces in the sheared schist areas with smaller angular pieces in the areas of basalt. Since the rocks are steeply dipping to the east, fairly steep slopes could be maintained along the east lock wall.

(5) Area 4 - Western Passage and Indian River.

(a) Tidal Dams. Two dams are proposed for area 4. A deep dam would cross the Western Passage between Moose and Deer Islands, and a shallower dam would be located between Deer and Indian Islands. The Moose Island abutment area was explored by shallow water drill hole 203-D which encountered about 30 feet of granular material resting on basalt bedrock. Deep water drill hole 108-D encountered 51 feet of similar granular material. The north abutment for the proposed dam is a sandy beach area. This evidence indicates that a large portion of this dam would be resting on granular material. The famous whirlpool, known locally as the "Old Sow," is located about 1200 feet northwest of drill hole 108-D. The Fairchild sonic survey located bedrock at a depth of 375 feet in the bottom of the whirlpool area. About 1200 feet from the center of this whirlpool, at the proposed dam crossing, granular material is found about 150 feet higher and at a depth of 230 feet, indicating a bottom slope of about 1 on 8. It has been concluded that the fines have been washed out of this relatively high overburden resulting in a sandy, gravelly overburden at the proposed dam crossing. Settlement of this granular material under a tidal dam does not appear likely.

The proposed dam between Deer and Indian Islands would be located over high bedrock between the two islands. Exploration near the center of the Indian River channel, in deep water drill hole 113-D, located about 20 feet of granular material resting on basalt bedrock. This granular overburden thickens at each side of the proposed crossing but appears to be compact enough so that it would settle very little under the proposed loading. In the Indian River channel, north of the axis of the proposed dam, a layer of soft clay occurs (as indicated by drill hole 110-D). Since the outer portion of the dam would extend over this clay, the north slope would be flattened or a berm would be constructed to obtain adequate foundation stability.

(b) Filling Gates. The data from drill holes S-17 and S-18 and reconnaissance of the surface exposures of rock in the proposed gate area on Deer Island Point show several types of rocks which have undergone considerable metamorphism. Many of the rocks are quartzose and schistose with basalt dikes interbedded throughout. Some fissile argillite beds grade into schistose rocks near the volcanic flow rocks. A large fault in the Western Passage produced many shear planes in the rocks which have recrystallized under heat and pressure. The rocks display dips from vertical to 65° east with the strike trending N10°E. All the rocks would provide suitable foundations for intake gates as the sheared rocks are recrystallized and strong. The main faulted area is located in the deeper portion of Western Passage and more than 1500 feet from the proposed gate location.

(c) Navigation Lock and Approaches. Overburden at the proposed lock site adjacent to Dog Island, consisting of a clayey, silty sand with a small amount of gravel, overlies bedrock in most of the lock area. At drill hole S-7, this overburden is 38 feet thick. Due to irregularities in the bedrock surface, this thickness varies considerably in the lock area. The rock outcropping along the alignment for this lock is principally a dense, fine-grained basalt with numerous fractures and little jointing. Some well-cemented basalt flow breccia and amygdaloidal basalt occurred in some of the core drilled in this vicinity. Most of the rock has a massive appearance but it tends to be brittle and much of it would shatter into small pieces if blasted heavily for excavation.

(6) Area 5 - Carryingplace and Johnson Coves.

(a) Powerhouse. Most of the powerhouse excavation would be in basalt and rhyolite which are in the form of volcanic flows or intrusions consisting of dikes or sills. Some cemented flow breccia would also be excavated. These igneous rocks are dense, fine-grained and strong. Numerous fractures or small cracks occur in these rocks which are healed with calcite and other minerals. Some interbedded shale and minor amounts of conglomerate occur in the volcanic rocks located at elevations mainly above the powerhouse foundation level. These shales are indurated and strong, and locally grade into slates and fine-grained silty sandstones with indistinct bedding. Small fractures and slickensided surfaces along small joints occur which are healed with calcite. Distinct joint patterns are not apparent in any of the rocks outcropping in the immediate area.

(b) Intake Channel. Much of the area in the Carryingplace Cove vicinity was investigated by Cooper in 1928 by means of a few drill holes and numerous wash borings. In 1935 and 1936, the U.S. Army Corps of Engineers investigated much of the area with drill holes, test pits, and jet probings. During the present investigations, three power auger holes were drilled and five hand auger borings were made. The logs of power auger holes and hand auger borings are shown on plate 2-13. The logs of the 1935-36 drill holes are shown on plates 2-14, 2-15, and 2-16. This information indicated that it would be necessary to excavate about 19 million cubic yards of overburden in the powerhouse and channel areas. Much of this material is located in the intake channel area. All of this material is silty clay with the exception of about $1\frac{1}{2}$ million cubic yards in the land and beach areas between Johnson and Carryingplace Coves which consists of gravelly sands with silt lenses covering the clay. Lenses of fine sand and some silt are also found in the clay near the land areas surrounding Carryingplace Cove. Considerable rock excavation would also be necessary for the intake channel. Rock which would be removed consists of rhyolite, basalt, shale and small amounts of slate, sandstone and conglomerate.

(c) Powerhouse Tailrace. Excavation for the powerhouse tailrace would be similar to that for the intake channel. The Fairchild sonic survey showed excellent penetration into the overburden, which is generally taken to indicate presence of clay. The bedrock topography is considerably rougher than the bottom topography. The rock excavation would be similar to the rock excavation for the powerhouse.

(d) Switchyard. The proposed switchyard would be located on a fill across a saddle between Mathews Island and a small island located about 600 feet to the northwest. This saddle is above water at low tide. Bedrock ranges from three to seven feet below the bottom and the overburden is composed of weathered granular material from the islands. Bedrock is rhyolite and basalt.

(e) Tidal Dam. A low tidal dam about 2400 feet long would extend from Mathews Island to Moose Island across a tidal flat which is exposed during low tides. Bedrock ranges from a few feet to as much as 25 feet below the overburden surface. This overburden is composed of granular material near the shore and over most of the area with some clay in the deeper depressions in the irregular bedrock surface. Very little settlement is anticipated for a relatively low structure at this location. Bedrock is composed of rhyolite, shale and minor amounts of intrusive diabase.

(7) Area 6 - Quoddy Roads.

(a) Tidal Dam. The Quoddy Roads area was explored by deep water hole 107-D drilled in the channel about 2000 feet west of the proposed dam crossing. This hole showed 49.5 feet of stiff clay from el. -29.8 to el. -79.3 m.s.l. Bedrock consists of black metamorphosed hard shale with fairly flat, obscured bedding. The deepest part of the pre-glacial channel through Quoddy Roads was apparently located north of drill hole 107-D. The Fairchild Sonoprobe showed good penetration into the sediments at the proposed dam crossing to depths of about 100 feet. It appears probable that the sediments are thicker in the deepest part of the pre-glacial channel.

(b) Navigation Lock. The proposed small navigation lock in the Quoddy Roads area would be located just south of Duck Point at the southerly end of Campobello Island. Drill hole S-2 on Duck Point encountered eight feet of basalt overlying dark gray to black, slaty and indurated shale with some quartzose lenses and beds. The basalt capping terminates between Duck Point and the lock site. The bedding of the shale strikes S45°W and dips about 24° southeast. This shale is dense, hard, and brittle with tight bedding planes except where movement has occurred along the bedding. It will tend to fracture when excavated, producing tabular pieces with the thickness often controlled by bedding planes. Geologic structure is shown on photograph 2-8.

g. Embankment Materials.

(1) General. To secure the least expensive project, as much of the required excavation as possible should be used in construction of the tidal dams, and all borrow needed for these dams should be secured from the most economical source. Use of structure excavation and selection of borrow sources for construction of tidal dams and cofferdams depends largely on suitability of the materials for placement under water in rapid tidal currents. Materials available from structure excavations and prospective borrow sources are discussed separately below. Both major and minor sources considered for development are described.

(2) Materials Available from Structure Excavation.

(a) Overburden. As previously mentioned, approximately 17 million cu. yd. of silty clay would be excavated to form the intake channel and tailrace at Carryingplace Cove. Overlying the clay in the isthmus between Johnson and Carryingplace Cove is about $1\frac{1}{2}$ million cu. yd. of granular material which would be excavated to form the intake channel. Excavation for the filling and emptying gates and the approaches to these gates and for navigation locks would also provide considerable amounts of granular material. The thickness of this material varies greatly as it fills in depressions and covers the rough topography of the bedrock surface. In the Letite Passage area, about

400,000 cu. yd. of granular material may be excavated at the filling gates. Drill hole 201-D in this area encountered 7 feet of granular material below the excavation grade for the gates. The granular material from this area could be used in the proposed dam between Dry Ledge and McMaster Island or in the low dam between the intake gates and the Canadian mainland. In the Head Harbour Passage area some granular material appears on Sandy Ledge as small beaches around portions of the three island land areas and in the channels as evidenced by the 14 feet of sandy gravel encountered in drill hole 202-D. An average of three feet of this material in the approach and structure areas would result in about 300,000 cu. yd. of overburden excavation. Excavation for the filling gates on the lower end of Deer Island would also encounter small quantities of granular material on the island. Beach deposits occur principally along the southern tip of the island and along the east side of the island in Indian River. Granular material ten feet in thickness was encountered in drill hole 206-D in Indian River, indicating extent of overburden to be excavated for the approach channel to the gates. It would appear that a minimum of 300,000 cu. yd. of this material would be excavated in the channels and from the gates on both sides of the island. Approximately 200,000 cu. yd. of silty sand and some gravel would be excavated at the proposed lock near Dog Island. Estimated quantities of overburden stated herein are based on interpretation of composite geologic data from all available sources and are larger than would be computed only from the maps shown in appendix 1.

(b) Rock. The rock excavation at the proposed powerhouse, gate, and lock locations would produce material which could be used in the dams. Much of this rock is fine-grained, dense, and brittle and would tend to break into stone of small size. Some of the metamorphosed sediments would break into tabular pieces with the longest dimension two to three times greater than the shortest. Random fractures and occasional shear planes would cause some of the rock to break into large stone. Excavations for the gates and approach areas in the Letite Area would be in more massive rock formations and could produce much of the riprap and derrick stone necessary for the dams in that area. If the excavations fail to produce sufficient rock of large size needed in this area, it appears that additional diabase-type rock can be quarried in the immediate vicinity.

(3) Materials Available for Embankment Borrow.

(a) General. The first phase of the present investigation of construction materials consisted of a complete review of data available from the exploration work performed in 1935 and 1936, and field reconnaissance of the areas previously investigated. In view of the larger scope of the present plan, the area covered by the earlier investigation was expanded to include the principal offshore islands and that part of the Canadian mainland contiguous to Passamaquoddy Bay. Reconnaissance of construction-material sources extended over an area of approximately 500 square miles. Field work performed during the investigation has been sufficient to establish the presence of adequate quantities of suitable materials for construction of the tidal project. The location of the materials sources considered for evaluation in this report are shown on plate 2-3. These sources include some which were previously considered in 1936. Important areas where limited exploration work was performed are shown on this plate by large circles. Secondary sources where little or no exploration was performed are shown by small circles. Information obtained and specific features of local areas are discussed in the following paragraphs.

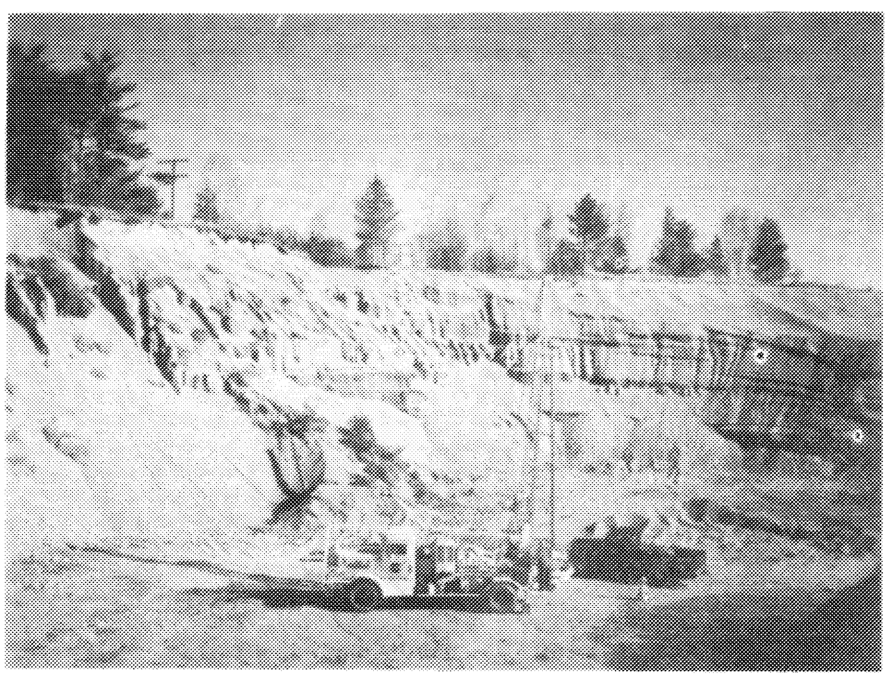
(b) Digdeguash - St. George Area. The coastal area between the Digdeguash River on the west and St. George on the east, extending north from Passamaquoddy Bay for 10 to 20 miles to some granite hills, was explored as a unit for possible borrow areas. The overburden in this area consists of glacial till which occurs as a thin, discontinuous mantle on the ridges and slopes of the hills, and deposits of sand and gravel. The largest single deposit of sand and gravel occurs near Bethel (plate 2-3). Other noteworthy deposits occur adjacent to the valley of the Magaguadavic River near St. George. The Bethel deposit occurs as a glacial outwash terrace about a mile long and a half mile wide with a flat surface except where it is interrupted by several rock hills. A large pit, as shown in photograph 2-9, has been opened at the west end of the terrace as a source for road construction material. Subsurface exploration consisting of 13 power auger holes, 6 to 37 feet deep, were concentrated in the part of the terrace considered most feasible for project development. The location of these borings and a record of the exploration are shown on plate 2-9. The portion of the terrace investigated would yield about 4 million cu. yd. of sand and gravel. The remainder of the terrace should yield an additional 12 million cu. yd., conservatively estimated. Bedrock below the deposit is predominantly basalt with some rhyolite and interbedded shales.

(c) St. George - Letite Area. The portion of the Canadian mainland lying south of the Magaguadavic River between St. George and Letite was investigated separately for borrow sources. The area consists of several rock hills interspersed with fairly level terrain, in places containing peat bogs. Overburden on the rock hills consists of a thin mantle of till. Several small beach deposits of sand and gravel are found along the road rimming the north and west side of the area. Larger sand and gravel deposits of glacial origin are located in the vicinity of St. George. All of these deposits are smaller and less favorably located than the previously described Bethel deposit, and accordingly have not been considered as sources for construction material for the tidal project. Bedrock exposed along road cuts and outcropping along the shore is predominantly basalt and related intrusive rock. Rhyolite flows and dikes, and interbedded shales, may occur in minor amounts since they generally are found associated with the basalt flows in the general area. An area containing marine silt and clay is found on the north shore about one mile east of Mascarene (plate 2-3). The deposit extends from the shoreline, southward to the adjacent road. A strip about one-half mile wide was explored by five hand-auger borings to an average depth of penetration of ten feet. It appears from the preliminary exploration performed, that a limited amount of impervious material could be obtained from this site.

(d) Deer, Indian, Pendleton and McMaster Islands. Deer Island and the adjacent smaller islands to the east are characterized by an extremely rocky, hilly, terrain extending to the shoreline. Overburden on the hills consists of a thin mantle of till. Several small terraces occur on the southwest side of Deer Island which appear to be glacial outwashes of gravelly, silty sand. Three very small raised beach deposits were also found on Deer Island which already have been depleted to a considerable extent for road material. A small beach deposit of recent origin is located near the north end of Indian Island. The principal bedrock found on the islands is basalt with minor amounts of rhyolite and interbedded shales, partially metamorphosed. Several outcrops of Perry conglomerate were noted on the west side of Pendleton and McMaster Islands. A large diabase mass occurs in the vicinity of Northwest Harbour on Deer Island and outcrops of this same type of rock occur on the southeast side of McMaster Island. Of the foregoing, the terraces of granular material and the large diabase masses are potential sources of construction materials for the tidal project.

The largest outwash terrace extends northward from Cummings Cove toward Fairhaven, plate 2-3. The north end of this terrace was explored by seven power auger borings from 21 to 57 feet deep at locations shown on plate 2-11, which also shows the record of exploration. It is estimated that about 500,000 cu. yd. of gravelly sand could be developed from this part of the terrace. A narrower part of the terrace extending southerly to Cummings Cove was explored by one power auger boring which disclosed 27 feet of silty sand. The face of the bluff at Cummings Cove is about 50 feet in height and is of gravelly, silty sand. This part of the terrace contains about

Photograph 2-9 General View of Materials in Bethel Terrace Deposit.



Photograph 2-10 General View of Materials in Dennysville Deposit.

500,000 cu. yd. of material making a total of about 1 million cu. yd. for the areas investigated in this terrace.

Another outwash terrace was found on the neck of land west of Fairhaven (plate 2-3). A field estimate, based on inspection of exposures, indicates that about 400,000 cu. yd. of gravelly silty sand would be available from this source.

Two prominent rock outcrops at Northwest Harbour (plate 2-3) were investigated by five diamond drill holes to determine suitability of the intrusive diabase rock for coarse aggregate, riprap, and large stone. The boring locations and record of the exploration are shown on plate 2-8. It was found that about 4 million cu. yd. of tough, hard, durable, medium-textured rock would be available on the basis of the topography of the area and the limited drilling accomplished. It is expected that selective quarrying could produce 10 to 20 percent of stone sizes in the 5- to 10-ton range.

(e) Eastport-Perry Area. On the peninsula extending from Perry to Eastport, Maine, the overburden consists of glacial till, marine silt and clay, and sand and gravel. The till overburden generally is found in thin patches on the higher rocky areas. Marine silt and clay occur in the low areas in the vicinity near Eastport. Terrace and raised beach deposits of sand and gravel are found scattered over the area with the larger deposits being located north of Eastport on Moose Island in the vicinity of Johnson Cove. The deposit is not continuous, being interrupted by rock exposures, and consists principally of gravelly, silty sand with some interbedded clay. About 1 million cu. yd. of granular materials would be available from this source. Only negligible amounts of overburden are found in the portion of the area north of the above described deposit. Bedrock is predominantly basalt and rhyolite flows with some interbedded shale.

The basalt flow rock at Shackford Head was explored by five diamond drill holes in 1936, and three additional holes during this survey principally to investigate suitability of material for concrete aggregates. The boring locations and the record of the exploration are shown on plate 2-6. The rock is hard, dense and very fine-grained, and contains numerous incipient close fractures throughout the rock mass. These incipient fractures would cause the material to break out in pieces smaller than one cubic foot in size when quarried.

(f) Campobello Island. The portion of Campobello Island north of Welshpool (plate 2-3) is rough and rocky with a thin till blanket partially covering the bedrock hills. South of Welshpool, the overburden is a thick mantle of unconsolidated material, consisting principally of glacial outwash with some reworked till. The outwash was deposited as a broad plain interrupted by a few rock exposures and several rock cored hills. A large barrier beach is found along the entire shore line at Herring Bay. Till is exposed at the base of the slopes along parts of the shoreline from Friar Bay to Duck Point. The bedrock underlying the northern part of the island is chiefly basalt with minor amounts of rhyolites, cherty argillites and meta-shale. Large masses of diabase are found at Man of War Head, and at Hannabury Hill. Diabase also occurs in the several rock hills which crop out above the outwash plain and in several promontories on the southern part of the island. Occasional outcrops of cherty argillites and shale can be observed along the southern shore.

Exploration for sand and gravel was limited to a small segment of the outwash plain where eight power auger borings 19 to 46 feet deep were drilled at locations shown on plate 2-12, which also shows the record of exploration. Exposures of gravelly, silty sand, ranging in height from 10 to 50 feet, extend for over one-half mile along the shore of Friar Bay. On the east side of the island, south of the barrier beach at Herring Bay, exposures extend about 3,000 feet in a southerly direction and range in height from 10 to 30 feet and show similar material. Using depths estimated from the exposures, and the area of the terrace, it has been estimated that at least 5 million cu. yd. of gravelly, silty sand would be available from this area. In addition, about 500,000 cu. yd. of sand and gravel could be obtained from the barrier beach at Herring Bay.

Limited exploration was performed in the massive, diabase ridge at Man of War Head (plate 2-3) to locate a potential quarry site for production of coarse aggregate, riprap and large stone. Exploration consisted of five diamond drill holes for which the boring locations and record of the exploration are shown on plate 2-7. The diabase was found to be a tough, hard, durable, medium-textured rock of which about 6 million cu. yd. would be available according to estimates based on the explorations and the topography of the ridge. A hill situated to the west of the ridge is a part of the diabase intrusion and could be used for additional rock. It is expected that selective quarrying could produce about 10 to 20 percent of stones in the 5- to 10-ton range at both locations.

A mass of rock similar to that at Man of War Head is located at Hannabury Hill near the north end of the island. No exploratory work was performed at this site; however, examination of the rock mass indicates it to be suitable for a quarry site to produce riprap and large stone. Based on rock exposures, it appears that about 3.5 million cu. yd. of rock would be available at this site.

(g) Lubec - West Quoddy Head Area. The Lubec-West Quoddy Head area was investigated particularly for materials which could be used for the proposed dam at Quoddy Roads. The overburden on the hill slopes and rock ridges consists of a thin, discontinuous mantle of glacial till. Shallow deposits of gravelly, silty sand occur as fringe terraces above sea level around Treat Island and West Quoddy Head. A large deposit of gravelly, silty sand is located west of Lubec. Between Lubec and West Quoddy Head is a considerable expanse of marine clay and silt which is exposed at low tide. Marine clay also occurs in the lowland and valley areas adjacent to shore and below the sand and gravel deposits at West Quoddy Head. Diabase is the principal bedrock in the area with outcrops at both West Quoddy Head and Lubec, and along the east side of Seward Neck. Rhyolites and basalts occur at Treat Island. Shale outcrops occur along the shore from West Quoddy Head to Lubec. The rock mass at West Quoddy Head was explored by two diamond drill holes. The rock is a tough, hard, durable, medium-textured diabase suitable for concrete aggregate, riprap and large stone. About 15 million cu. yd. of rock are available at this site. Selective quarrying could produce about 20 percent of stones in the 5- to 10-ton range, which would be sufficient for project requirements.

(h) Haycock Harbor Area. The area south of Cobscook Bay and east of U.S. Highway No. 1, including the vicinity of Haycock Harbor, was investigated as one area. The glacial till overburden occurs in thin patches along the side slopes and on top of most of the hills and ridges. Marine silts and clays generally occur below el. 100 m.s.l., in the valley and lowland areas. Deposits of gravelly, silty sand are found as old beach deposits along lower slopes of rock knobs and ridges generally at about el. 100. The deposits are limited in size, shallow in depth, and widely scattered. The principal bedrock in the area is diabase which occurs generally throughout the southern portion of the area and is found as prominent knobs and ridges in the northern part. Rhyolites, basalts, and shales underlie the lower elevations particularly in the northern part. For the auxiliary pumped-storage reservoir site considered in this vicinity in 1936, it was found necessary to explore many separate deposits to develop sufficient materials for embankment fill. No surficial deposits were considered suitable at the time for the production of natural concrete aggregate and the current investigations did not disclose any potential sources of materials for the proposed tidal power project.

(i) Dennysville Area. Significant deposits of glacial sand and gravel, principally in eskers and terraces, occur in Dennysville (plate 2-3) and extend to the northwest and west of the town. The sand and gravel mound near the Dennysville railroad station was explored in 1936 by means of test pits. It was recommended as the sole source of sand for concrete aggregate for the tidal power project under construction at that time. Since the deposit was deficient in the coarse aggregate sizes, a crushed-rock source was recommended for use with the sand obtained from this deposit. The deposit was explored further in 1957 by seven power-auger borings ranging in depth from 10 to 35 feet. The boring locations and record of exploration are shown on plate 2-10. Although this particular deposit has been utilized during the intervening years, it is estimated that about 300,000 cu. yd. of sand are still available. Other sources nearby could be developed if necessary. Photograph 2-10 shows a general view of materials in the Dennysville deposit.

(j) Cobscook Bay - Boyden Lake Area. The overburden in the area north of Cobscook Bay to the granite upland of Boyden Lake and lying east of the Maine Central Railroad (plate 2-3) consists of glacial till, marine clay, and deposits of sand and gravel. The till overburden in the area is generally thin, and covers the slopes and tops of hills and ridges in a discontinuous mantle. Marine silts and clays of undetermined thickness occur in the valley and lowland areas below about el. 100. Deposits of gravelly, silty sand are found as old beach deposits along the many knobs and ridges which trend in the direction of Cobscook Bay. The beach deposits are generally located at about el. 100 and are usually limited in size, shallow in depth and widely scattered. Deposits of sand and gravel, too small for further consideration, are located around the shore of Boyden and Pennamaquan Lakes. One significant sand and gravel deposit occurs as a glacial terrace along the west bank of the Pennamaquan River extending from near the outlet of Pennamaquan Lake to the village of Pembroke. The deposit has been extensively utilized for road construction material. This source was not considered for aggregate in 1936 as it was found to be shallow in depth and was considered uneconomical to develop. The principal bedrock in the area consists of rhyolite and basalt flows, shales and Perry sediments, with the shale most prominent. Diabase intrusives are scattered throughout the area and several of the smaller masses make promontories along the Cobscook Bay shoreline.

(k) Boyden Lake - Calais Area. The granite upland north of Pennamaquam and Boyden Lakes to Calais, Maine, and east of the Maine Central Railroad (plate 2-3) is rough and rocky with numerous fresh water lakes and small streams. The glacial till overburden which covers the bedrock of the hills and knobs is generally thin and scattered. Some glacial clay is found in the swamp areas adjacent to the fresh water lakes. Silt and clay occur on some of the slopes dipping to the coastline. Only three deposits of sand and gravel were found of sufficient size to merit a reconnaissance. One deposit occurs along the shore of the St. Croix River extending from Hilchin Point north for about 500 feet and lies east of U.S. Highway No. 1. It is being extensively used for highway construction. Another source of sand and gravel is a nearby terrace to the west of U.S. Highway No. 1. A third deposit is the glacial esker extending from Round Pond towards Calais, Maine, along the right-of-way of the Maine Central Railroad.

Exploration was performed in the area in 1936 to locate material for the several dams proposed to inclose the Calais auxiliary pumped-storage reservoir. Investigations were widespread because many areas were necessary to fulfill the borrow requirements at that time. The largest source of the few significant borrow areas found at that time was located about one-half mile southwest of Calais, Maine. The deposit is situated on the high ridge and side hill slope overlooking the St. Croix River. Up to 7 million cu. yd. of material suitable for impervious fill were indicated in this deposit. An esker on the west side of the area was explored for an aggregate source in 1936 and was considered as the second choice for concrete sand. Also, it was considered as a source of embankment materials for the proposed dams on the west side of the auxiliary pumped-storage reservoir site. Reconnaissance in 1957 indicated a limited amount of reworked till in a ridge area northwest of Perry, Maine, but this material does not appear suitable for large-scale development. Bedrock of the area is predominantly granite with some outcrops of the Perry conglomerate appearing along the shoreline and at Little Douchet Island in the channel of St. Croix River. The granite outcrop at Devils Head near Calais, Maine, was considered as a source of large stone in 1936. The granites of this area would be reliable sources of sound aggregate and of large stones.

(1) St. Croix River - Digdeguash River Area. The Canadian mainland east of the St. Croix River to the Digdeguash River was examined as one area. The northern half of the area displays a rough, rocky terrain containing many fresh water lakes. The southern half, particularly the St. Andrews peninsula, is gently sloping. Surficial deposits consist of a thin till blanket mantling the bedrock surface, and an occasional deposit of sand and gravel. A relatively large glacial deposit of sand with some gravel occurs at Sand Point situated about six miles north of St. Andrews along the St. Croix River shore. Sand and gravel occur in other very small and scattered deposits in this area but none were found which merited consideration for a major construction material source. The bedrock in the portion

of the area lying essentially north of Chamcook Lake (plate 2-3) consists mostly of granites, gabbros and allied rocks. A band of rhyolites, basalts, and interbedded shales stretches as a wedge across the Chamcook Lake area narrowing considerably to the east. These rocks also project up into the Digdeguash River valley for several miles. The St. Andrews peninsula is underlain principally by the red Perry sediments.

(4) Sources Considered for Development.

(a) Overburden. The 17 million cu. yd. of silty clay which would be excavated from Carryingplace Cove for the powerhouse intake channel would provide most of the impervious material needed for the tidal dams and cofferdams. About 2.5 million cu. yd. of gravel and sand for the tidal dams could be obtained from granular overburden at proposed structure sites. The remainder could be secured from beach and terrace deposits in the general project area. Largest sources of borrow of granular materials are on Campobello Island, and in the Bethel terrace in New Brunswick.

(b) Rock. Much of the material for the rockfills in the tidal dam would come from structure excavations. The Man of War Head quarry site is considered the most feasible source of large stone for riprap and for difficult closure operations. The smaller-sized rock waste material could be separated from the large stone and moved by scow to locations where rockfill embankment material is needed. Photographs 2-11 and 2-12 show an existing jetty at Lubec, Maine, which was constructed of stone of the same quality as found at Man of War Head.

(5) Consideration of Alternate Sources.

(a) Overburden. The several deposits of granular materials occurring on land in the proximity of the proposed dams as discussed above could be used in the dams and cofferdams where economically feasible. Selection of alternate sources would depend largely on method and sequence of construction of dams and cofferdams.

(b) Rock. In addition to the major rock quarry proposed at Man of War Head other sources of large stone located near structure sites include the diabase intrusive masses at West Quoddy Head, at Hannabury Hill on Campobello Island northeast from Man of War Head, and near Northwest Harbour on Deer Island.

Photograph 2-11 General View of Existing Stone Jetty at Lubec, Maine.

Photograph 2-12 View Showing Size and Shape of Stones in Jetty at Lubec, Maine.

h. Concrete Aggregates.

(1) General. Investigations to determine availability and suitability of materials within the tidal project vicinity for production of concrete aggregates have been described in preceding paragraphs covering geology and field explorations. Laboratory tests and analyses of principal types of available materials considered for concrete aggregates are discussed below. Sources of coarse and fine aggregate are summarized herein. The considerations leading to selection of those sources proposed for project development are discussed.

(2) Laboratory Tests and Analyses.

(a) Laboratory Facilities. Preliminary examination and gradation tests of materials considered for concrete aggregates were made in the project field laboratory at Eastport, Maine. Selected samples were sent to the Materials Laboratory of the South Atlantic Division of the U.S. Army Corps of Engineers in Marietta, Georgia, for petrographic analyses, determination of thermal expansion, and durability in concrete mixtures. Assistance in petrographic analyses was obtained from the Ohio River Division Laboratories, Mariemont, Ohio, and the Waterways Experiment Station, Vicksburg, Mississippi, both of the U.S. Army Corps of Engineers.

(b) Test Program. After thorough reconnaissance of the project vicinity and review of materials explorations conducted during prior studies of the tidal project, representative samples of materials were selected from sources considered most appropriate for use in project construction for laboratory tests and analyses. Portions of rock cores, 2 1/8 inches in diameter, were chosen from explorations in prospective quarry locations at West Quoddy Head, Shackford Head on Moose Island, Man of War Head on Campobello Island, and an outcrop near Northwest Harbour on Deer Island for petrographic analysis. In addition, bulk samples were selected from quarry rock at Shackford Head, and natural aggregates from the Bethel terrace, east of the Digdeguash River in New Brunswick, from deposits on the southerly part of Deer Island, and from sand and gravel deposits in Dennysville, Maine. Location of these sources are shown on plate 2-3. These bulk samples were subjected to elementary tests for classification and preliminary tests generally made by the U.S. Army Corps of Engineers to investigate suitability of concrete aggregates. These latter tests include petrographic analyses, determination of thermal coefficient of expansion, and durability of concrete mixtures as indicated by many cycles of alternate freezing and thawing of test beams. In planning the specific test program of the current survey, cognizance was taken of the substantial amount of investigation performed by the U.S. Army Corps of Engineers in 1935-37. The mineral aggregates were first examined for structural competence of individual specimens of the various rock types in each sample. Subsequently, these aggregates were used in concrete mixtures in various combinations to investigate the durability of concrete and compatibility of prospective combinations of coarse and fine aggregates.

(c) Technical Properties of Concrete Aggregates and Mixtures. Results of petrographic analysis of rock cores from the four prospective quarry sites considered have been concisely stated in a petrographic report from the Ohio River Division Laboratories of the U.S. Army Corps of Engineers and is quoted, in part, as follows:

"INTRODUCTION:

"Eighteen samples of NX size igneous rock cores from the area of Passamaquoddy Bay, Maine, were submitted by the New England Division for examination by the South Atlantic Division Laboratory. These samples were identified as follows:

Quarry	Exploration	SAD Lab. No.	Depth (Feet)
West Quoddy Head	M-1	82/510	25.9 - 26.4
" " "	M-1	82/510	79.9 - 80.3
Shackford Head	M-3	82/511	6.6 - 7.2
" " "	M-3	82/511	80.6 - 81.0
" " "	M-4	82/512	24.6 - 25.1
" " "	M-4	82/512	82.9 - 83.4
" " "	M-5	82/513	28.9 - 29.4
" " "	M-5	82/513	47.6 - 48.1
Man of War Head	M-9	82/514	38.9 - 39.4
" " "	M-9	82/514	60.0 - 60.6
" " "	M-21	82/515	19.9 - 20.5
" " "	M-21	82/515	66.2 - 66.7
Northwest Harbour	M-13	82/516	58.9 - 59.5
" " "	M-13	82/516	101.9 -102.5
" " "	M-13	82/516	151.7 -152.3
" " "	M-15	82/517	40.1 - 40.6
" " "	M-15	82/517	76.6 - 77.1
" " "	M-15	82/517	119.6 -120.6

"All samples were examined under the stereoscopic microscope. On the basis of this examination, the samples were separated into two general rock types. The samples from West Quoddy Head, Man of War Head and Northwest Harbour were grouped into one type, and those from Shackford Head were grouped as the other type. One thin section of each type was prepared for mineralogic and textural determination. Other check tests on individual samples were made by index of refraction determinations on mineral grains removed from the samples.

"DISCUSSION:

"The samples from West Quoddy Head, Man of War Head and Northwest Harbour are a dark greenish-gray, fine- to medium-grained crystalline basic igneous rock classified here as a diabase. Although the mineralogic composition varies somewhat from sample to sample, the rock is composed predominantly of pyroxene (probably augite) and intermediate to basic plagioclase feldspar. A prominent and well distributed accessory mineral is magnetite which is probably titaniferous. Although the rock is generally free from any indications of weathering, some of the feldspar is very slightly kaolinized. A variety of minor accessory minerals also occur. Although the texture varies, most of the samples show euhedral crystals of feldspar with the pyroxene occurring as interstitial filling.

"This rock type is hard, dense and tough. No textural nor structural feature was observed which would adversely affect the use of this stone as concrete aggregate or riprap. No material known to be chemically reactive with the free alkalies in cement was found.

"The samples from Shackford Head are a dark gray to black, fine-grained microcrystalline basic igneous rock which is classified as a basalt. The mineralogic composition was not positively determined, but it is similar to the diabase. The dominant minerals probably are pyroxene and a plagioclase feldspar with a large amount of well distributed magnetite which gives the black color to the rock. The rock generally has a microcrystalline salt-and-pepper texture with a small amount of brown interstitial basic glass.

"The basalt is a hard, dense somewhat brittle rock. All of these core samples (82/511, 512, and 513) are highly jointed and fractured. These fractures are weakly cemented by secondary calcium carbonate.

"CONCLUSIONS:

"On the basis of the samples examined, the following conclusions have been reached as a result of the petrographic examination:

1. All of the diabase (Lab. samples 82/510, 82/514, 515, 516, and 517) is a hard durable rock suitable for use as concrete aggregate and riprap.

2. All of the basalt (Lab. samples 82/511, 512, and 513) is a hard durable stone except for numerous closely spaced fractures. On the basis of samples examined, it is considered to be satisfactory for the production of $1\frac{1}{2}$ inch maximum sized aggregate, to be of fair quality for production of 3-inch maximum size aggregate, and probably of poor quality for the production of any sizes larger than 3 inches.

3. No material known to be chemically reactive with free alkalies in cement was found in any of the samples."

Laboratory tests were made of bulk samples of quarried rock from Shackford Head, and of natural gravel and sand from the Bethel terrace, from Deer Island, and from Dennysville. Results of these tests are shown in comparative arrangement on plate 2-39. These tests indicate that both coarse and fine aggregate can be obtained from the quarry site at Shackford Head, but that the natural aggregate sources are suitable for fine aggregate only.

(3) Major Sources Considered for Development. After consideration of the results of tests for suitability, the availability of adequate quantities, and the production and transportation problems, it was concluded that coarse aggregates for concrete could be most advantageously obtained for the major structures from a diabase rock quarry at Man of War Head on Campobello Island. For fine concrete aggregates, either crushed rock from the same quarry at Man of War Head or sand from the Bethel terrace would be suitable.

(4) Alternate Sources. Preliminary consideration was given to producing concrete aggregates for the gates and lock in the Letite area from diabase rock existing on the mainland just northward, and aggregates for the locks at Quoddy Roads from similar rocks at Quoddy Head. Alternate studies for concrete aggregates for the tidal powerhouse at Carryingplace Cove included consideration of coarse aggregate from Shackford Head and fine aggregate composed of sand from Dennysville. However, savings in hauling costs involved in using several nearby sources appeared to be offset by additional cost of acquiring and developing numerous sources rather than a single but more remote source.

i. Concrete Mixtures.

(1) Cement. All concrete for the powerhouse, gates, and locks would be made with Portland cement conforming to U.S. Federal Specification SS-C-192, Type II (moderate heat of hydration), with no admixtures except an air-entrainment agent.

(2) Construction Water. Adequate quantities of good quality fresh water could be obtained in the vicinity of each major tidal project structure for the production of concrete aggregates and for the manufacture and curing of concrete. Location and areas of possible local water supplies are presented in appendix 4, "Basic Hydrologic Data." Accordingly, construction programs and cost estimates have been based on using fresh water for these purposes. However, water could be used in the processing of concrete aggregates if fresh water rinsing were used to prevent formation of a salt residue on the aggregate particles.

(3) Concrete Mix Designs. Concrete mixes were designed for the proposed tidal structures to determine the quantities of materials for cost estimates. Mixtures were considered using both natural and manufactured aggregates in order that the least costly combination could be selected. The mixtures were designed in accordance with the conventional requirements of the U.S. Army Corps of Engineers to provide maximum durability in sea water and in a climate with frequent freeze - thaw cycles, and for the use of 6-, 3-, and $1\frac{1}{2}$-inch maximum aggregate sizes. Composition of design mixes using crushed rock as coarse aggregate with either manufactured or natural sand as fine aggregate are shown below.

Concrete Mix Designs
Manufactured Sand and Crushed Rock

(Proportions for one cubic yard of concrete)

Item	Mix A	Mix B	Mix C
Maximum aggregate size, inches	6	3	1.5
Water			
Proportion, gal./bag	6.0	5.5	5.0
Volume, cu.ft.	3.21	3.68	4.01
Weight, pounds	200.0	229.0	250.0
Cement			
Specific gravity	3.0	3.0	3.0
Proportion, barrels	1.00	1.25	1.50
Volume (solid), cu.ft.	1.91	2.39	2.87
Weight, pounds	376	470	564
Fine aggregate			
Specific gravity	2.85	2.85	2.85
Proportion of total aggregate	0.28	0.32	0.35
Volume (solid), cu.ft.	6.12	6.80	7.04
Weight, pounds	1,088	1,209	1,252
Coarse aggregate			
Specific gravity	2.85	2.85	2.85
Volume (solid)			
6- to 3-inch size, cu.ft.	5.67	--	--
3- to $1\frac{1}{2}$-inch size, cu.ft.	4.10	5.55	--
$1\frac{1}{2}$- to 3/4-inch size, cu.ft.	2.52	3.99	5.88
3/4-inch to No. 4 sieve, cu.ft.	3.47	4.70	7.19
Weight			
6- to 3-inch size, pounds	1,007	--	--
3- to $1\frac{1}{2}$-inch size, pounds	727	986	--
$1\frac{1}{2}$- to 3/4-inch size, pounds	448	708	1,045
3/4-inch to No. 4 sieve, pounds	615	834	1,277
Concrete			
Density (solid), pounds/cu.ft.	165.2	1,643	1,625
Air content (assumed), percent	2.0	2.5	3.0
Density (with air), pounds/cu.ft.	162.0	160.3	157.8

Concrete Mix Designs
Natural Sand and Crushed Rock

(Proportions for one cubic yard of concrete)

Item	Mix A	Mix B	Mix C
Maximum aggregate size, inches	6	3	1.5
Water			
Proportion, gal./bag	6.0	5.5	5.0
Volume, cu.ft.	3.21	3.68	4.01
Weight, pounds	200	229	250
Cement			
Specific gravity	3.0	3.0	3.0
Proportion, barrels	1.00	1.25	1.50
Volume (solid), cu.ft.	1.91	2.39	2.87
Weight, pounds	376	470	564
Fine aggregate			
Specific gravity	2.70	2.70	2.70
Proportion of total aggregate	0.28	0.32	0.35
Volume (solid), cu.ft.	6.12	6.80	7.04
Weight, pounds	1,030	1,127	1,185
Coarse aggregate			
Specific gravity	2.85	2.85	2.85
Volume (solid)			
6- to 3-inch size, cu.ft.	5.67	--	--
3- to $1\frac{1}{2}$-inch size, cu.ft.	4.10	5.55	--
$1\frac{1}{2}$- to 3/4-inch size, cu.ft.	2.52	3.99	5.88
3/4-inch to No. 4 sieve, cu.ft.	3.47	4.70	7.19
Weight			
6- to 3-inch size, pounds	1,007	--	--
3- to $1\frac{1}{2}$-inch size, pounds	727	986	--
$1\frac{1}{2}$- to 3/4-inch size, pounds	448	708	1,045
3/4-inch to No. 4 sieve, pounds	615	834	1,277
Concrete			
Density (solid), pounds/cu.ft.	163.1	161.2	160.0
Air content (assumed), percent	2.0	2.5	3.0
Density (with air), pounds/cu.ft.	159.8	157.2	155.2

2-05 AUXILIARY PUMPED-STORAGE POWER DEVELOPMENTS

a. General. Among the auxiliary power sources considered for the proposed international Passamaquoddy tidal power project are the pumped-storage projects described in appendix 11, "Auxiliary Pumped-Storage Developments." Locations of these projects are shown on plate 2-40. Geology, foundation conditions, and construction materials for the sites considered are described in the following paragraphs.

b. Existing Data. During the tidal project studies made by the U.S. Army Corps of Engineers in 1935 and 1936, investigations were made of potential pumped-storage project sites at Calais and Haycock Harbor, located as shown on plate 2-40. Reconnaissance and exploration data which are available from these early studies were reviewed during the initial phase of the current survey, and applicable portions have been used in studies described in the following paragraphs. Particularly pertinent were reports on each of these sites by Irving B. Crosby, Consulting Geologist.

c. Regional Geology.

(1) Topography. The land surface of the Passamaquoddy Bay area is one of low to moderate relief. It is characterized by numerous rock hills, knobs, and ridges which rise above the marine terraces, stream valleys, and lowlands. Most of the hills are less than 300 feet high and a few peaks exceed 500 feet in height. In the northern portion of the area, which includes the Digdeguash River basin, the prominent hills and ridges display a trend in a southeast direction. The elongation appears to control the major drainage patterns in the area and follows the general direction of many of the bays and estuaries which indent the coastline. This parallelism is in harmony with the structural trend of the hard rock formations and has in a large measure been accentuated by glaciation. The coastline of Passamaquoddy Bay is very irregular and is characterized by long bays, estuaries and many islands. Much of the shoreline is rocky, but many reaches bordering the lowlands are formed of low bluffs cut in clay or silty gravels. As a result of past glaciation, much of the land surface is covered with fresh water lakes, ponds, and marshes which are drained by numerous small local streams. The St. Croix River, with a drainage area of about 1,600 square miles, is the largest stream in the area. Lesser streams include the Dennys, Digdeguash and Magaguadavic Rivers.

(2) Bedrock. Bedrock in the Passamaquoddy Bay area consists of sedimentary rocks interbedded with volcanic flows complicated by the presence of abundant intrusive masses and by extensive faulting. The Quoddy shale of Silurian age is regarded as the oldest rock in

the area. A thick sequence of volcanic flows which are chiefly basalt and rhyolite with varying thicknesses of interbedded shale and tuff overlie the Quoddy shale. These flows are the predominant rocks in the area and have undergone considerable deformation during and subsequent to their deposition. Faulting was more extensive than folding and the flows and sediments display only a low to moderate degree of metamorphism. A few large faults and numerous faults of moderate displacement occur in the area. Lying unconformably above the rocks of Silurian age are the sandstones and conglomerates of the red colored Perry formation of Devonian age. These sediments have been subjected to much less deformation than the older rocks, displaying gentle dips and smaller local faults. This formation is derived, for the most part, from the erosion of granites as evidenced by the coarse granitic fractions. Within these rocks are the coarser-grained igneous masses of gabbro and diabase identified as the intrusive mineralogical counterparts of the volcanic flow (extrusive) rocks consisting of finer-grained basalt and rhyolite. Local and relatively small outcrops of these intrusives are found in the Cobscook Bay area and on Deer and Campobello Islands, and a larger mass of diabase lies southwest of Lubec, Maine. Granites of late Silurian and early Devonian age occur generally in the northern part of the area.

(3) Surficial Deposits. Glacial action in the area appears to have been intense. The severity of ice movement can be deduced by the rounding of the elongated rock-cored hills and the polished, striated, and gouged rock surfaces. There is a general lack of glacial drift. A relatively thin and discontinuous surficial mantle of till is found on hillsides and low areas. Sand and gravel deposits are sparse. Apparently the ice-movement eroded more than it deposited since its effects were confined mostly to rounding and smoothing the higher hills. The general absence of glacially deepened valleys and the thin mantle of drift indicate that very little glacial debris was incorporated in the ice.

d. Digdeguash Site.

(1) General. The international nature of the current tidal power project survey led to consideration of pumped-storage sites in New Brunswick near the tidal project in addition to the two United States sites considered during the 1935-37 studies. The most feasible Canadian site is in the Digdeguash River valley at the north end of Passamaquoddy Bay. The general project location is shown on plate 2-40.

(2) Field Exploration. The Digdeguash dam site was investigated in 1957 when 5 test borings were drilled by Geocon Limited of Montreal, Quebec, Canada. Two of the three proposed saddle dams necessary to enclose the upper part of the reservoir

were also investigated by a test boring at each site. The locations of these borings are shown on plates 2-41 and 2-42, and logs of the holes are shown on plate 2-42. Reconnaissance was carried out at the same time to determine the bedrock conditions in the reservoir, to locate embankment and aggregate materials, and to investigate possible reservoir losses by salt water intrusion through the reservoir rim.

(3) Site Geology and Structure Foundations. The dam site is located about a quarter of a mile above the Digdeguash Falls where the river empties into Passamaquoddy Bay. Bedrock at the dam site is dense fine-grained basalt which is massive and shows only minor weathering. Some minor grouting would be required to seal off the relatively tight fractures and joints existing in the rock. The dam site is forested and a thin deposit of glacial till also partially mantles the bedrock. This overburden would be removed before placing the embankment material. Where weathering occurs in the upper part of the bedrock, a shallow cutoff trench would be necessary. Considerable rock excavation will be necessary in the tailrace area below the powerhouse. This rock, which forms the Digdeguash Falls, is mainly a very hard siliceous rhyolite and is difficult to drill. Basalt will probably occur in the powerhouse excavations with the contact between the two types of rock occurring between the falls and the powerhouse site. The bedrock is entirely adequate as a foundation for all the structures required for the project. Since bedrock is generally tight with most joints and fractures closed or healed, and with relatively impervious glacial till in the rock saddles below proposed reservoir level, salt water leakage from the reservoir would not be a problem.

(4) Embankment Materials.

(a) Impervious Fill. Sufficient impervious material in the form of glacial till would be available for the impervious core of the main dam and for the saddle dams along the sides of the reservoir basin. The till is found as a relatively thin mantle on the valley bottom and on the sides of the valley walls within the reservoir basin.

(b) Random Fill. The structure and channel excavation in the dam site area and in the saddle dam areas would supply a mixture of till and rock suitable for the random fill requirements.

(c) Pervious Fill. Pervious material could be obtained from the extensive gravel and sand terrace located along Highway No. 1, about 2 miles east of the Digdeguash River.

(d) Rock for Exterior Slope Protection. Rock for the shell of dams and for riprap could be obtained from rock excavation at the dam site and from sources close to the saddle dams.

(5) Concrete Aggregates. Basalt and rhyolite rocks from excavations for structures and channels at the dam site are of suitable quality for processing into concrete aggregate. Unlimited quantity of sound rock occurs in the project vicinity which could be quarried if required. Ample quantities of gravel and sand suitable for concrete fine aggregate occur in the Bethel glacial outwash terrace located approximately three miles east of the proposed dam site. Coarse aggregate from this source is not suitable as previously developed in this appendix. Sufficient fine aggregate for a concrete dam could be developed from these sources.

(6) Concrete Mixtures. All concrete for principal structures would be made with durable local aggregates, using Portland cement conforming to U.S. Federal Specification SS-C-192, Type II (moderate heat of hydration) with no admixture except an air entrainment agent. Adequate fresh water of suitable quality for production and curing of concrete is available from the Digdeguash River.

e. Calais Site.

(1) General. The most feasible site for an auxiliary pumped-storage project on the United States side of the tidal project is at Calais, Maine, in the general location shown on plate 2-40. Site plan with exploration locations is shown on plate 2-43. Boring logs are shown on plates 2-44 through 2-48, inclusive.

(2) Field Exploration. Subsurface explorations performed by the U.S. Army Corps of Engineers in 1935 and 1936 were sufficient for the current survey except that a small amount of additional reconnaissance was needed for adequate evaluation of the site conditions.

(3) Site Geology and Structure Foundations. Overburden at the Calais site consists of glacial deposits which range from a few feet to over 60 feet in thickness. This overburden is of a sandy or clayey texture and is underlain by granite bedrock. A small amount of settlement might occur in localized areas where proposed dams would be founded on clay and a small amount of blanketing might be necessary in the sandy areas. Leakage of salt water from the reservoir would not be a problem in either overburden or bedrock. The bedrock at the proposed powerhouse site occurs at a sufficiently high level for the proposed construction, and is of adequate strength.

(4) Embankment Materials. Suitable pervious and impervious materials for proposed dams are available in several areas which were investigated in 1935. A few of the prospective borrow areas are shown on plate 2-43; other areas outside of the immediate structure locations are not shown. Rock for outer shells of dams and for riprap could be obtained from rock excavation for proposed structures or from sources reasonably close to embankment sites.

(5) Concrete Aggregates. Numerous outcroppings of granite within the immediate project vicinity are excellent sources of material for concrete aggregates. Deposits of sands and gravels suitable for processing into concrete fine aggregate are located in the general project area but somewhat further from structure locations than the granite sources.

(6) Concrete Mixtures. Concrete for the powerhouse and other principal structures would be made with durable rock aggregate using Portland cement conforming to U.S. Federal specification SS-C-192, Type II (moderate heat of hydration) with no admixture except an air entrainment agent. Fresh water of suitable quality for production and curing of concrete is available from the numerous lakes in the area.

f. Haycock Harbor Site. The Haycock Harbor site located southwest of Lubec, Maine, was investigated in 1935. Investigations at that time indicated that the Calais site was more feasible for the pumped-storage development than Haycock Harbor. A review of these investigations made early during the current survey confirmed this conclusion and, for this reason, no further investigation was made for the Haycock Harbor site.

2-06 AUXILIARY RIVER HYDRO POWER DEVELOPMENTS

a. General. As developed in appendix 12, "Auxiliary River Hydro Developments," sites for the river hydro auxiliary to the proposed international tidal power project have been investigated on the upper Saint John River. Sites investigated include Rankin Rapids, Big Rapids, and Lincoln School, all of which are between 2 and 17 miles upstream from St. Francis, Maine, as shown on plate 2-49. Geology, foundation conditions, and construction materials for each of these sites are described in the following paragraphs.

b. Regional Geology. The upper Saint John River is located in the northern part of the Appalachian Province which extends from southeastern United States into the eastern part of Canada. This region is a semi-wilderness with no known mineralization. Upheaval of bedrock by mountain building movements created a rugged topography which has been reduced to rolling hills extending generally to elevations of 1,000 to 1,500 feet above sea level with occasional peaks over 3,000 feet in elevation. This topography was modified during more recent times by glaciation at which time a thin mantle of till was left on the hills and thicker glacial deposits filled the valleys with the result that the drainage system was altered. As a result, the Saint John River now flows in a valley which is 70 to 120 feet above the preglacial channel. Bedrock is composed of shale of Ordovician and Silurian ages which is usually calcareous with some sandy beds. This rock at one time was deeply buried and metamorphism has hardened the shales until they are very durable. These shales contain some slaty and quartzose zones. Crustal adjustments have tilted the rock until it is nearly vertical with the strike of the beds averaging about N50°E. The present channel of the Saint John River meanders above the preglacial channel so that rock is usually exposed on only one bank or the other along much of its present course. Overburden in this region is of glacial origin, and consists of glacial till, outwash materials, and kame deposits. Compact till fills many of the deeper valleys and contains considerable gravel and boulders which were derived mainly from the adjacent bedrocks. Some till was deposited along the upper slopes of the rock hills but only very little remains on the hilltops. The outwash materials of stratified sand and gravel terrace deposits containing substantial amounts of platy shale fragments occur along the sides of the present drainage system. Silt and sand deposits below stream level represent glacial lake deposits formed as the ice retreated. Occasional irregular kame terraces composed of locally derived gravels occur along preglacial valley walls. Earthquakes are not of serious concern in this region. Minor tremors occur from time to time in the St. Lawrence Valley region to the north and only an occasional earthquake of sufficient intensity to be noticeable to people has occurred in the vicinity.

c. Rankin Rapids Site.

(1) General. The Rankin Rapids site considered for development is located approximately three and one half miles upstream from St. Francis, Maine, as shown on plate 2-49.

(2) Field Exploration. The Rankin Rapids site was investigated in 1951 and 1952 when nine test borings were made. Exploration locations are shown on plate 2-50 with drill logs and geologic profile shown on plate 2-51. These data have been reported previously in an interim report to the International Joint

Commission by the International Saint John River Engineering Board, 6 April 1953, and entitled "Water Resources of the Saint John River Basin." During the current survey, the field work has been limited to detailed site reconnaissance and extension of investigation of prospective sources of construction materials.

(3) Site Geology and Structure Foundations. At the dam site, the Saint John River flows in a northerly direction over a shallow gravel and boulder bed about 550 feet wide. The preglacial bedrock valley extends under the left bank of the stream and is about 80 feet below present stream level. In this preglacial valley there is a deep deposit of compact glacial silt. The bedrock valley walls rise steeply and are covered generally by a dense glacial till with a terrace deposit of stratified sand and gravel just above stream level on the left bank. Bedrock consists of indurated shale striking N45°E with nearly vertical dip and occurs in both valley walls with an outcrop on the right bank near present stream level. This bedrock would provide entirely adequate foundations for all major concrete structures. This rock is also suitable for the tunnel construction contemplated. In view of the deep overburden in the valley bottom, the site is not favorable for construction of a concrete dam. It is, however, suitable for an earth dam. The dense glacial till is adequate to support an embankment of the height considered for development, using nominal slopes. Over the center valley section where the glacial silt occurs in the foundation, some flattening of side slopes would be required to insure stability of the embankment. Underseepage would not be a problem in the glacial till, but cutoff treatment would be necessary in the sand and gravel terrace deposit on the left bank.

The spillway would be located in the west abutment of the dam with a lined discharge channel extending down the left valley wall. Preliminary exploration in this area consisted of a single boring, BH-5, which penetrated five feet of compact glacial till over bedrock composed of diabase with numerous shale inclusions. Based on results of this boring and geological reconnaissance of the immediate vicinity, it is considered that bedrock would be structurally adequate for foundation of this spillway and channel and would occur at suitable location and elevation for project requirements.

The intake structure would be founded in rock on the right abutment with exposed penstocks leading to the powerhouse recessed into the valley wall. The powerhouse tailrace would be in a bedrock channel. Subsurface explorations conducted in 1951 were made at lower elevations than presently proposed for development of this site. However, based on results of these borings and a geological investigation of the right valley wall, it was concluded that bedrock would be encountered at shallow depth below ground surface and that this bedrock would be the same type of indurated shale as found generally throughout the project vicinity. Consequently, adequate foundation for all concrete structures appears assured.

Two 24-foot diversion tunnels would be located in shale in the right abutment. This shale is hard and dense with little alteration showing along cleavage planes and joints. Since the joints in these shales are relatively tight, very little grouting should be necessary. The tunnels would be excavated in a direction which is nearly normal to the strike of the steeply inclined beds which would tend to minimize overbreak.

(4) Embankment Materials. Materials existing at or near the dam site occur in sufficient quantities for construction of an earth dam. The glacial till is an excellent material for the impervious portion of the dam, having high shear strength and low permeability. The terrace deposits of sand and gravel are well suited for the pervious sections of the dam. Rock for slope protection can be developed from boulders in and along the stream channel, from proposed structure excavations, and from nearby bedrock exposures.

(5) Concrete Aggregates. The predominant native rock in the vicinity of the proposed project is shale, and the overburden which is largely derived from it contains numerous platy fragments. Preliminary reconnaissance indicated that these shale rocks and the sands and gravels with substantial amounts of platy fragments would not be suitable for production of durable concrete aggregates. The nearest known sources of commercially available aggregates are the limestone quarries in the vicinity of Presque Isle, Maine. Transportation would involve a rail haul of more than 80 miles, including about $3\frac{1}{2}$ miles of new trackage from St. Francis, Maine, to the project site. Outcrops of granite at Deboulie Mountain about 12 miles south of Rankin Rapids were found during a field reconnaissance for a nearer source. Megascopic inspection indicates that this rock is suitable for production of good quality concrete. Preliminary cost analysis indicates this source to be economically feasible for development of aggregates for the proposed project although the quarry site is now accessible only over logging roads.

(6) Concrete Mixtures. Concrete for proposed project structures would be composed of coarse and fine aggregate produced by quarrying the granite at the above-mentioned Deboulie Mountain.

Portland cement conforming to U.S. Federal Specification SS-C-192, Type II (moderate heat of hydration) would be used with no admixture except an air entrainment agent. Fresh water for mixing and curing concrete could be obtained from the Saint John River.

d. Big Rapids Site.

(1) General. Regional geology, availability of embankment materials, and concrete aggregates are substantially the same for the Big Rapids site as stated previously for the Rankin Rapids site, about 13 miles downstream as indicated on plate 2-49. Conditions pertaining specifically to the site are described in the following paragraphs.

(2) Field Exploration. Field exploration consisted of a careful site reconnaissance and eight core borings to determine subsurface conditions. Drilling and sampling was performed in 1957 under contract by Geocon, Ltd., of Montreal, Quebec, Canada. Locations of borings are shown on plate 2-52, with boring logs and geologic profile on plate 2-53.

(3) Site Geology and Structure Foundations. The dam site is located in a large bend in the Saint John River where the stream flows in a northerly direction as it approaches the proposed embankment centerline and turns to the east beyond it. This location is about six miles upstream from the confluence of the Saint John River and the Allagash River and near the center of a boulder-choked rapids section. The borings show that the preglacial valley is under the left abutment where the shale bedrock was located over 100 feet below the present stream level. This preglacial channel is filled with dense till containing numerous boulders and cobbles. Over 200 feet of this till is found immediately above the old channel. The surface of the till forms the left abutment on a fairly steep slope and rising to elevations considerably above the proposed top of the dam. The present stream is slowly degrading its channel, and since bedrock is exposed on the right bank, it is shifting towards the left bank and eroding the less durable glacial till. Cobbles and boulders up to 5 feet in diameter eroded from the till hillside choke the stream and form the long rapids section. On the right valley wall where the project structures would be located, the borings encountered shale bedrock from 13 to 30 feet below the ground surface. The embankment for the dam would be placed on impervious till with the exception of a few rock outcrops along the right bank. A shallow cutoff through the boulders, cobbles, and gravel would be necessary only in the stream valley.

Advantage has been taken of the bend in the river to locate the spillway approximately $\frac{1}{4}$ mile east of the east end of the dam. The spillway crest structure would be located in a saddle where rock is outcropping. The unlined spillway chute would follow a northerly direction along an existing small drainage course running over glacial till. The lower stilling basin would be excavated in rock which outcrops along the bank of the river at the lower end of the spillway. The diversion tunnels would be located under the ridge which forms the right abutment of the proposed dam and would be driven in shales and shaly sandstones entirely adequate for the 24-foot diameter proposed. The alignment of these tunnels is in a northerly direction and excavation will occur in vertical beds striking N50°E. The fractures and joints in the shale beds are mostly tightly healed and only minor grouting would be required. The proposed powerhouse and six penstocks would be founded on entirely adequate shale rock on the right abutment. The powerhouse and the outlet portal for the tunnels would be recessed into the rock abutment area about 1,500 feet from the present river channel. At this location the powerhouse foundation would be nearly 200 feet below the present surface. The slopes extending from the ground surface to the powerhouse would be mostly in rock which would stand on steep slopes due to the vertical dip of the rocks and their hardened nature. The strike of the beds is at an angle of 45 to 50 degrees with the direction of the outlet channel for the powerhouse and outlet works which would result in repeated offsets in the vertical beds encountered during excavation.

e. Lincoln School Site.

(1) General. The Lincoln School site would be developed as a low head project which would operate in conjunction with the Big Rapids project as an auxiliary to the proposed international tidal power project. The site is about 15 miles downstream from the Big Rapids site and about 2 miles downstream from the Rankin Rapids site as shown on plate 2-49. Regional geology is substantially the same as previously stated for the Rankin Rapids site.

(2) Field Exploration. Field exploration at the Lincoln school site consisted of site reconnaissance and three test borings. Drilling and sampling were performed in 1957 under contract by Geocon, Ltd., Montreal, Quebec, Canada. Location of borings and boring logs are shown on plate 2-54.

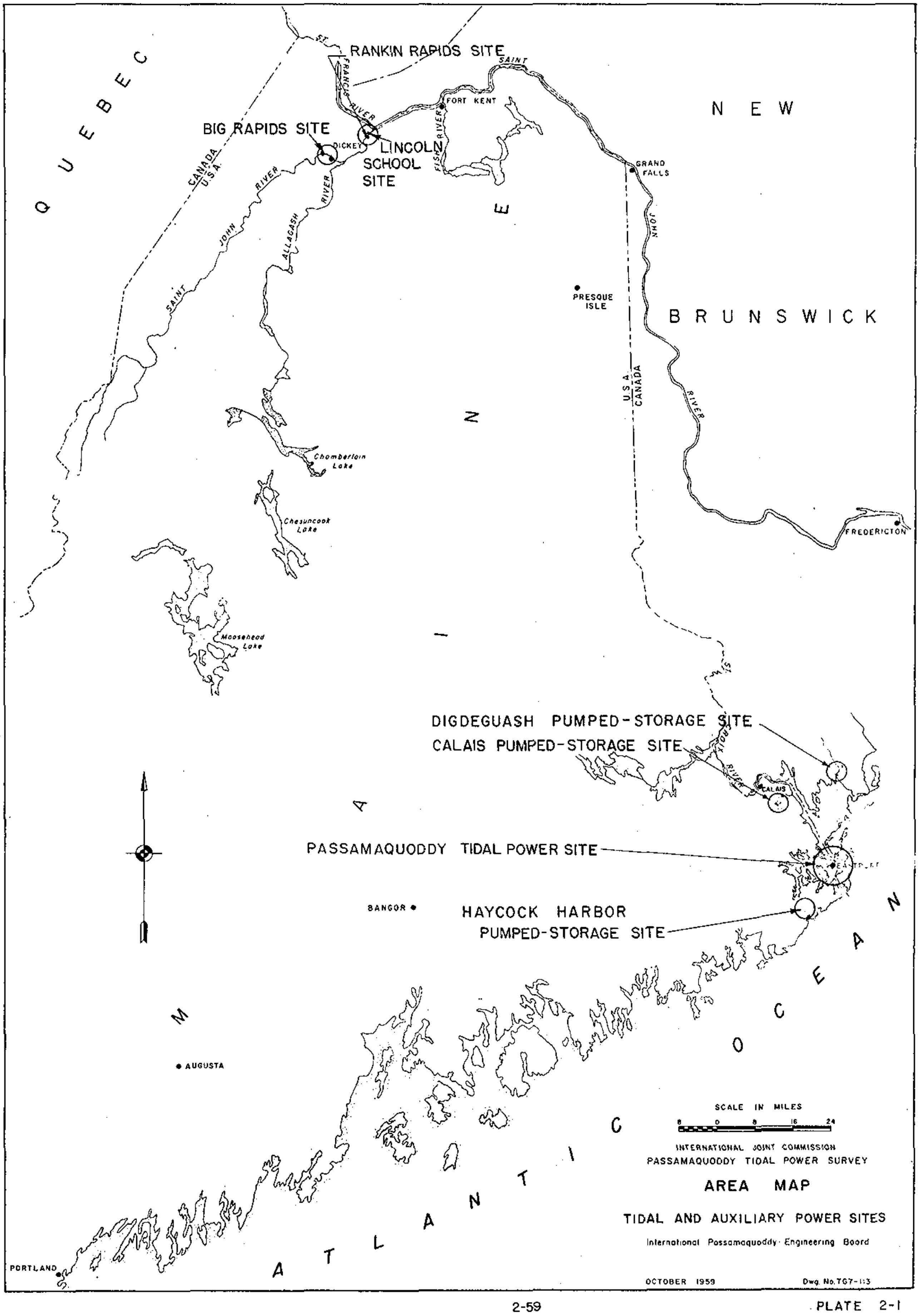
(3) Site Geology and Structure Foundations. The dam site is located along a straight stretch of the Saint John River where it flows in a northeasterly direction. The rocks are dipping about 85°

northwest and the strike is N50°E or approximately parallel to the river. Bedrock outcrops along both banks of the stream and since the beds are nearly vertical, the more resistant beds are found along the banks of the river and the less resistant beds are beveled forming a series of steep steps above and below stream level. Dense glacial till, 69 feet deep, was found overlying bedrock in a drill hole near the center of the present channel which lies above the pre-glacial channel. A thin layer of gravel and cobbles forms a bar in the channel below the centerline of the proposed dam site. From 15 to 30 feet of glacial till and terrace deposits cover bedrock on both abutments. The embankment for the dam would be placed on impervious glacial till which would require a shallow cutoff through the weathered and gravelly surface layers. Bedrock along the river banks is relatively unweathered so that careful scaling would be sufficient preparation for the embankment fill. The spillway chute and stilling basin would be located on the right abutment where they would be cut into competent shale bedrock. The powerhouse would be notched into rock in the left valley wall at left end of the earth dam. This rock is strong and will stand on steep slopes. The steepness of these slopes will vary to a small extent due to some differences in the hardness of the beds and to the different directions of the excavation in relation to the strike and steep dip of the beds.

(4) Construction Materials. The Lincoln School site is only two miles downstream from the Rankin Rapids site in a portion of the upper Saint John River Valley where available construction materials are essentially the same as previously described for the Rankin Rapids development. Ample quantities of compact glacial till, suitable for impervious core of an earth dam, and granular materials suitable for shell construction are available close to the dam site locations. Local materials are unsuitable for concrete aggregates. The nearest source of satisfactory aggregate is the granite at Deboulie Mountain approximately 12 miles south of the Rankin Rapids site as previously described.

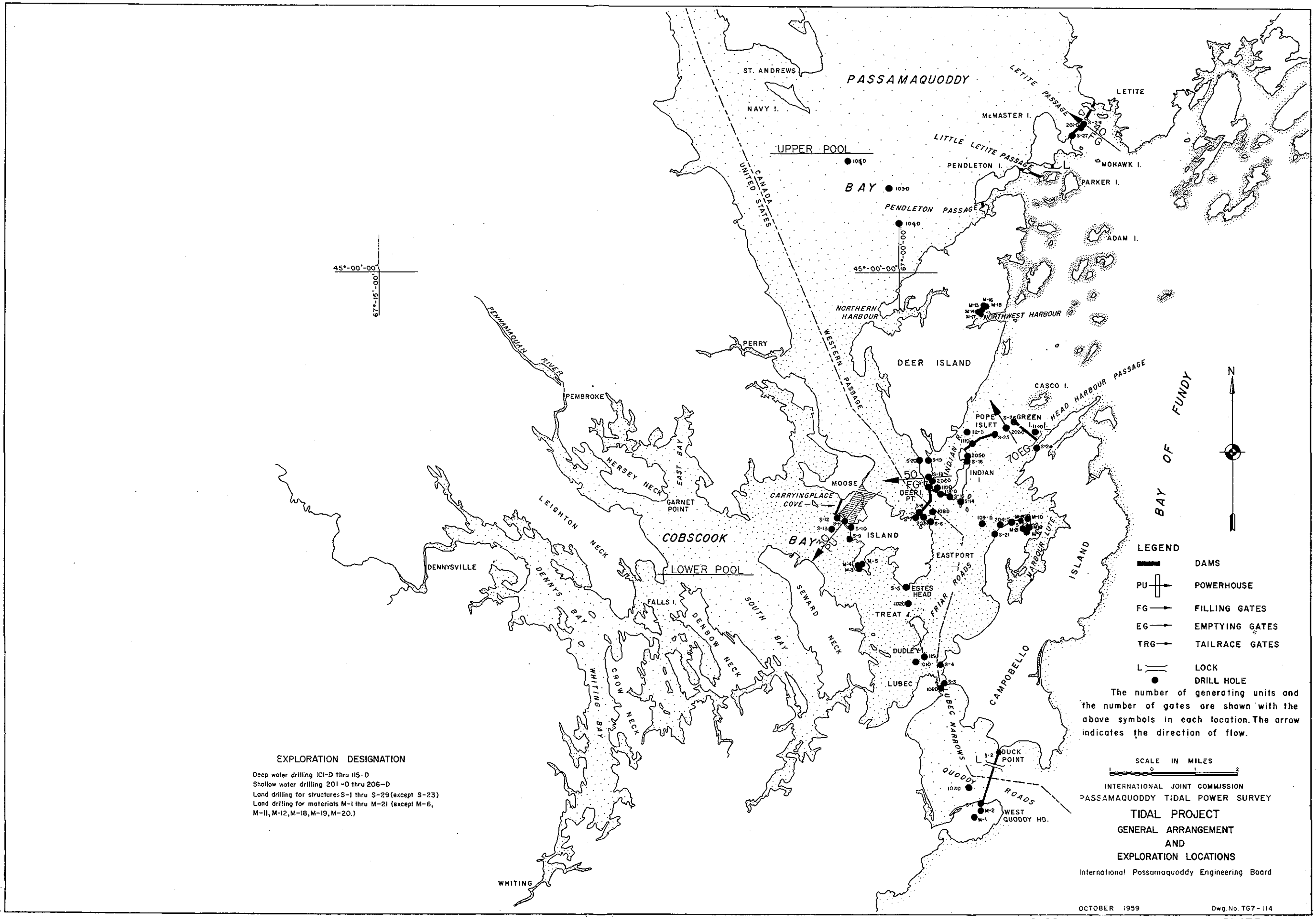
APPENDIX 2

PLATES



RANKIN RAPIDS SITE
BIG RAPIDS SITE
LINCOLN SCHOOL SITE
DICKEY
FORT KENT
GRAND FALLS
PRESQUE ISLE
QUEBEC
NEW BRUNSWICK
MAINE
CANADA U.S.A.
U.S.A. CANADA
ST. FRANCIS RIVER
SAINT JOHN RIVER
ALLAGASH RIVER
FISH RIVER
Chamberlain Lake
Chesuncook Lake
Moosehead Lake
FREDERICTON
ST. CROIX RIVER
DIGDEGUASH PUMPED-STORAGE SITE
CALAIS PUMPED-STORAGE SITE
CALAIS
PASSAMAQUODDY TIDAL POWER SITE
HAYCOCK HARBOR PUMPED-STORAGE SITE
BANGOR
AUGUSTA
PORTLAND
ATLANTIC OCEAN
SCALE IN MILES
8 0 8 16 24
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
AREA MAP
TIDAL AND AUXILIARY POWER SITES
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-1:3

PLATE 2-1


PASSAMAQUODDY
BAY
UPPER POOL
LOWER POOL
COBSCOOK
BAY
ST. ANDREWS
NAVY I.
LETITE PASSAGE
LETITE
McMASTER I.
LITTLE LETITE PASSAGE
PENDLETON I.
MOHAWK I.
PARKER I.
PENDLETON PASSAGE
ADAM I.
CANADA
UNITED STATES
45°-00'-00"
67°-15'-00"
67°-00'-00"
NORTHERN HARBOUR
NORTHWEST HARBOUR
DEER ISLAND
WESTERN PASSAGE
PERRY
PENNAMAQUAN RIVER
PEMBROKE
CASCO I.
HEAD HARBOUR PASSAGE
BAY OF FUNDY
POPE ISLET
GREEN
INDIAN I.
HERSEY NECK
EAST BAY
GARNET POINT
MOOSE
CARRYINGPLACE COVE
DEER PT.
ISLAND
EASTPORT
LEIGHTON NECK
DENNYSVILLE
DENNYS BAY
FALLS I.
DENBOW NECK
SOUTH BAY
SEWARD NECK
ESTES HEAD
TREAT I.
FRIAR ROADS
HARBOUR LUTE
ISLAND
CAMPOBELLO
DUDLEY I.
LUBEC
LUBEC NARROWS
DUCK POINT
QUODDY ROADS
WEST QUODDY HD.
WHITING BAY
CROW NECK
WHITING
N
LEGEND
DAMS
PU POWERHOUSE
FG FILLING GATES
EG EMPTYING GATES
TRG TAILRACE GATES
L LOCK
DRILL HOLE
The number of generating units and the number of gates are shown with the above symbols in each location. The arrow indicates the direction of flow.
SCALE IN MILES
0 1 2
EXPLORATION DESIGNATION
Deep water drilling 101-D thru 115-D
Shallow water drilling 201-D thru 206-D
Land drilling for structures S-1 thru S-29 (except S-23)
Land drilling for materials M-1 thru M-21 (except M-6, M-11, M-12, M-18, M-19, M-20.)
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL PROJECT
GENERAL ARRANGEMENT
AND
EXPLORATION LOCATIONS
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-114

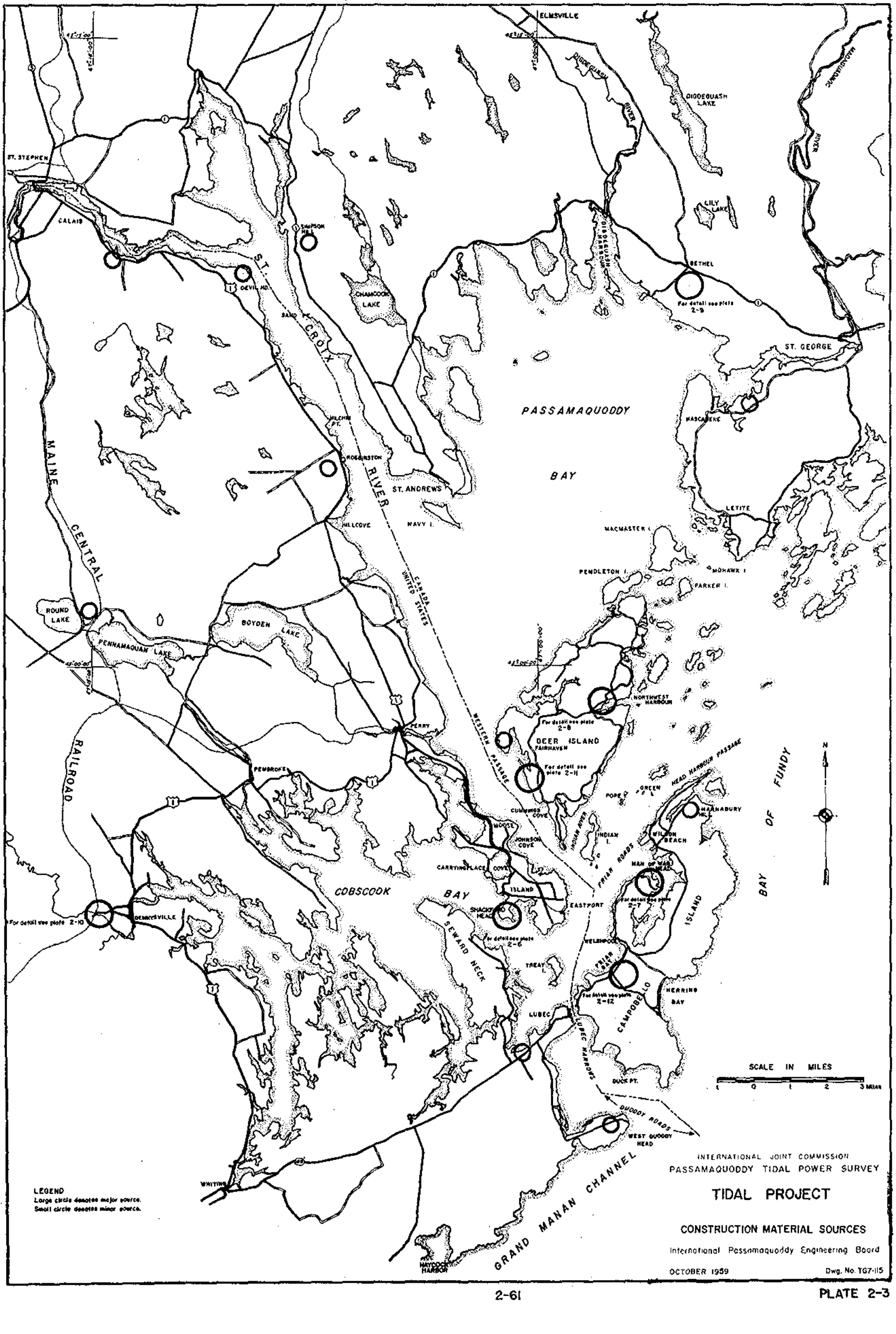
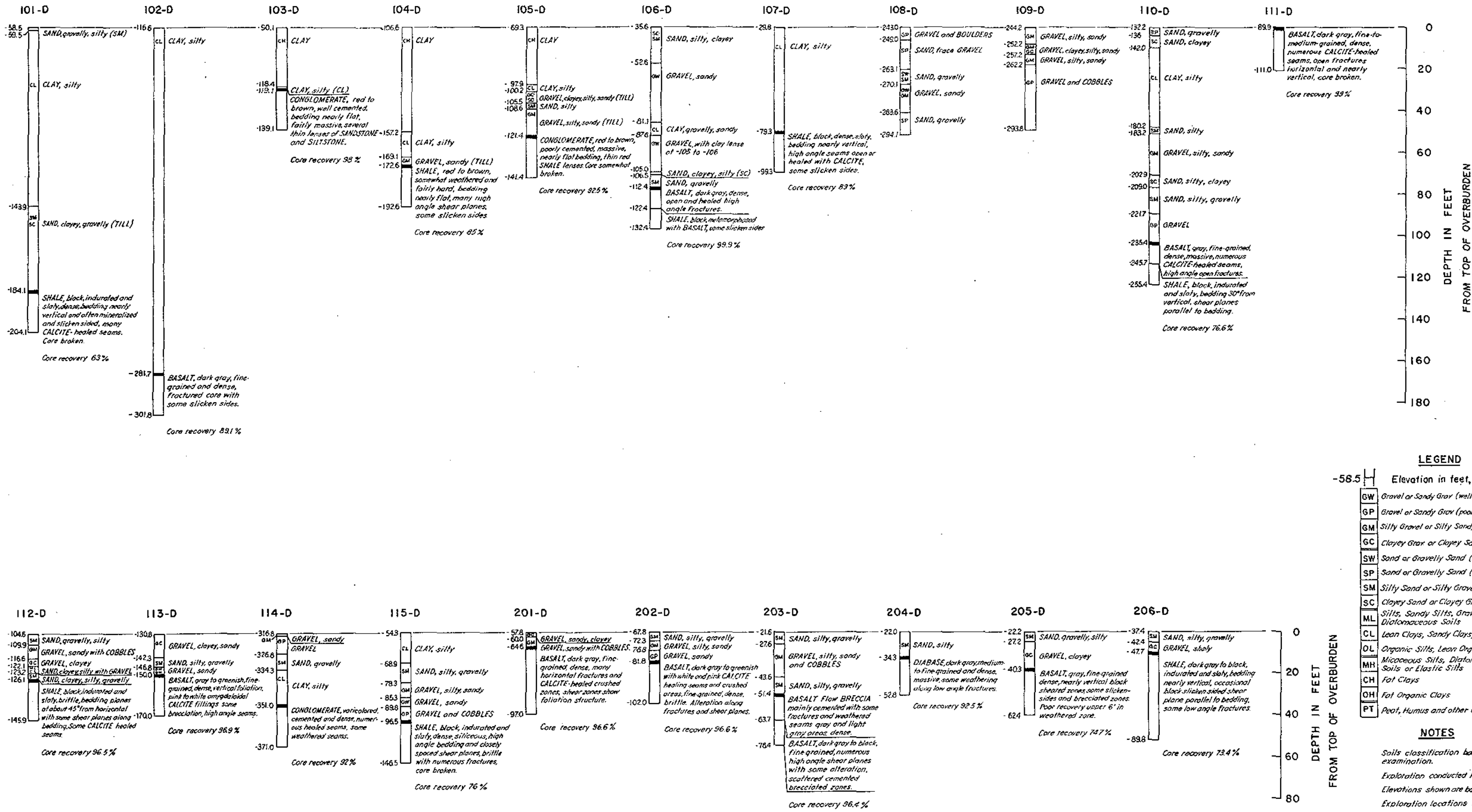

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL PROJECT
CONSTRUCTION MATERIAL SOURCES
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-115
LEGEND
Large circle denotes major source.
Small circle denotes minor source.
SCALE IN MILES
PASSAMAQUODDY
BAY
BAY OF FUNDY
COBSCOOK
BAY
ST. CROIX RIVER
GRAND MANAN CHANNEL
MAINE CENTRAL RAILROAD
CANADA
UNITED STATES
ST. STEPHEN
CALAIS
ELMSVILLE
DIGDEGUASH LAKE
DIGDEGUASH RIVER
MAGAGUADAVIC RIVER
LILY LAKE
BETHEL
For detail see plate 2-9
ST. GEORGE
MASCARENE
LETITE
MACMASTER I.
PENDLETON I.
MOHAWK I.
PARKER I.
CHAMCOOK LAKE
ST. ANDREWS
NAVY I.
HILLCOVE
ROBBINSTON
DEVIL HD.
ROUND LAKE
PENNAMAQUAN LAKE
BOYDEN LAKE
PERRY
PEMBROKE
NORTHWEST HARBOUR
For detail see plate 2-8
DEER ISLAND
FAIRHAVEN
For detail see plate 2-11
WESTERN PASSAGE
HEAD HARBOUR PASSAGE
CUMMINGS COVE
POPE
GREEN I.
INDIAN I.
INDIAN RIVER
FRIAR ROADS
WILSON BEACH
MAN OF WAR HEAD
For detail see plate 2-7
ISLAND
EASTPORT
MOOSE
JOHNSON COVE
CARRYINGPLACE COVE
SHACKFORD HEAD
For detail see plate 2-6
SEWARD NECK
TREAT I.
WELSHPOOL
FRIAR BAY
For detail see plate 2-12
CAMPOBELLO
HERRING BAY
LUBEC
LUBEC NARROWS
DUCK PT.
QUODDY ROADS
WEST QUODDY HEAD
DENNYSVILLE
For detail see plate 2-10
WHITING
HAYCOCK HARBOR

PLATE 2-3



LEGEND

-58.5 Elevation in feet, m.s.l.

- GW Gravel or Sandy Grav (well graded)
- GP Gravel or Sandy Grav (poorly graded)
- GM Silty Gravel or Silty Sandy Gravel
- GC Clayey Grav or Clayey Sandy Gravel
- SW Sand or Gravelly Sand (well graded)
- SP Sand or Gravelly Sand (poorly graded)
- SM Silty Sand or Silty Gravelly Sand
- SC Clayey Sand or Clayey Grav Sand
- ML Silts, Sandy Silts, Grav Silts or Diatomaceous Soils
- CL Lean Clays, Sandy Clays, Grav Clays
- OL Organic Silts, Lean Organic Clays
- MH Micaceous Silts, Diatomaceous Soils or Elastic Silts
- CH Fat Clays
- OH Fat Organic Clays
- PT Peat, Humus and other Organic Soils

NOTES

Soils classification based on laboratory examination.

Exploration conducted May to July, 1957

Elevations shown are based on mean sea level.

Exploration locations shown on Plate 2-2

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

RECORD OF EXPLORATION

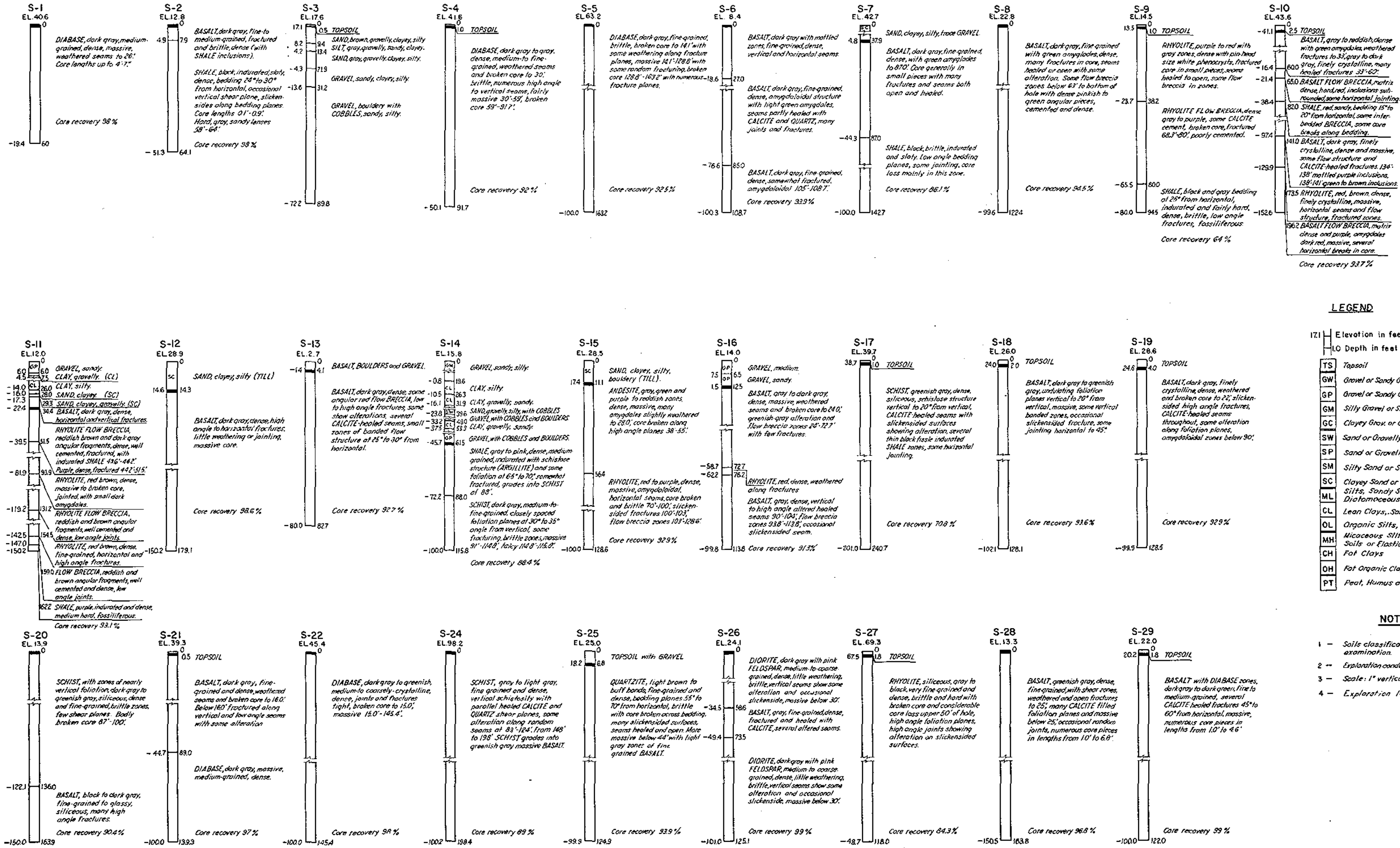
SUBAQUEOUS DRILLING, 1957

International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-116

PLATE 2-4



LEGEND

17.1 — Elevation in feet, m.s.l.
1.0 — Depth in feet

TS	Topsoil
GW	Gravel or Sandy Grav (well graded)
GP	Gravel or Sandy Grav (poorly graded)
GM	Silty Gravel or Silty Sandy Gravel
GC	Clayey Grav. or Clayey Sandy Gravel
SW	Sand or Gravelly Sand (well graded)
SP	Sand or Gravelly Sand (poorly graded)
SM	Silty Sand or Silty Gravelly Sand
SC	Clayey Sand or Clayey Grav Sand
ML	Silts, Sandy Silts, Grav. Silts or Diatomaceous Soils
CL	Lean Clays, Sandy Clays, Grav Clays
OL	Organic Silts, Lean Organic Clays
MH	Micaceous Silts, Diatomaceous Soils or Elastic Silts
CH	Fat Clays
OH	Fat Organic Clays
PT	Peat, Humus and other Organic Soils

NOTES

1 – Soils classification based on field examination.
2 – Exploration conducted from Sep.1957 to Jan.1958.
3 – Scale: 1" vertical = 20'.
4 – Exploration locations shown on Plate 2-2

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

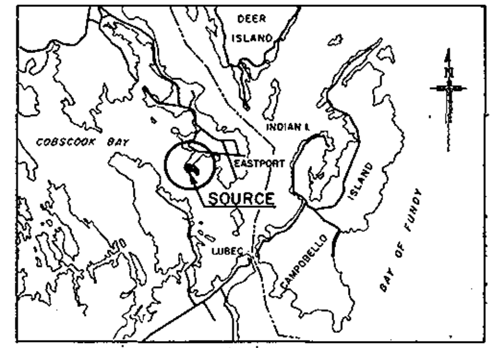
TIDAL PROJECT

RECORD OF EXPLORATION

LAND DRILLING FOR STRUCTURES, 1957

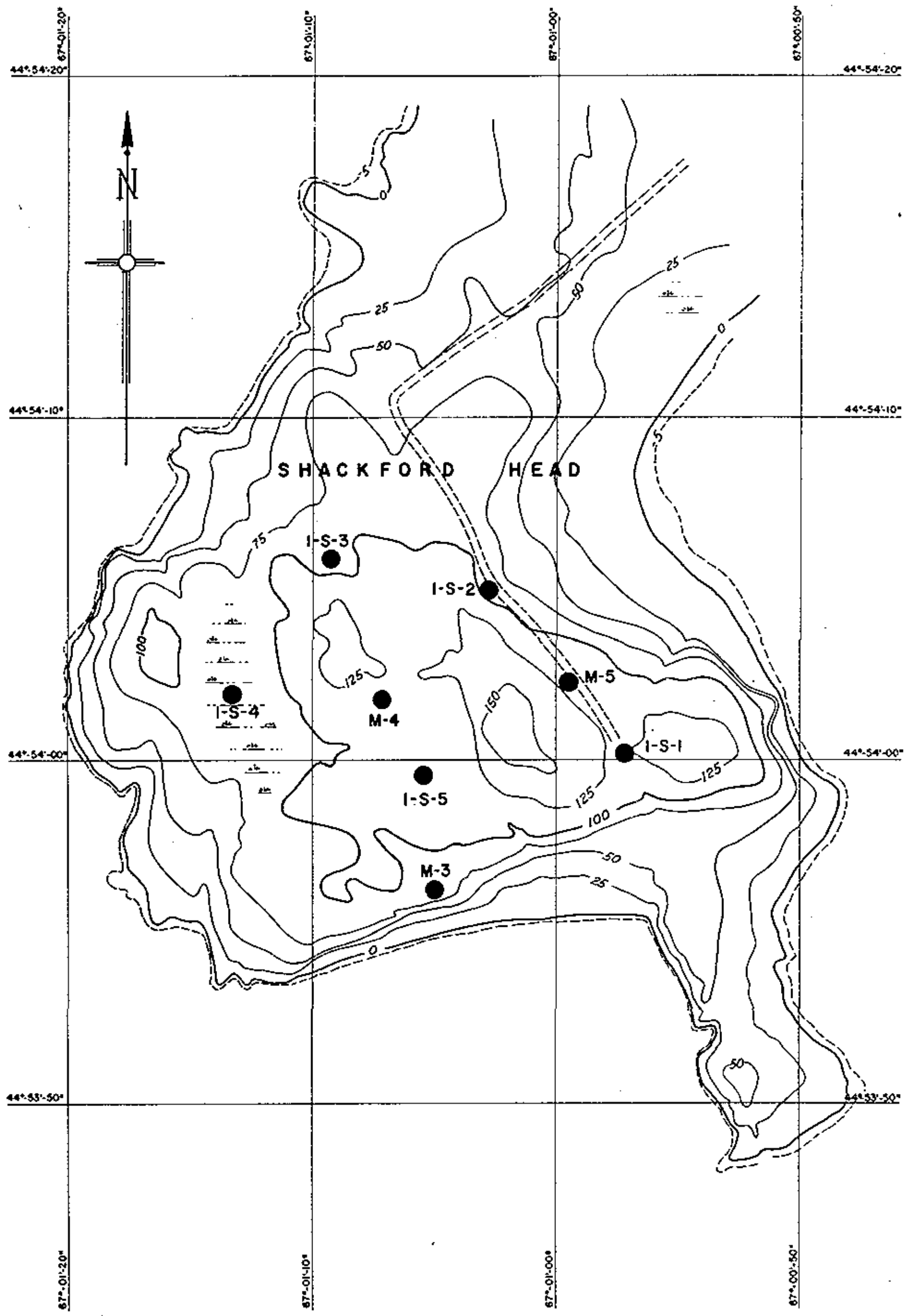
International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-117



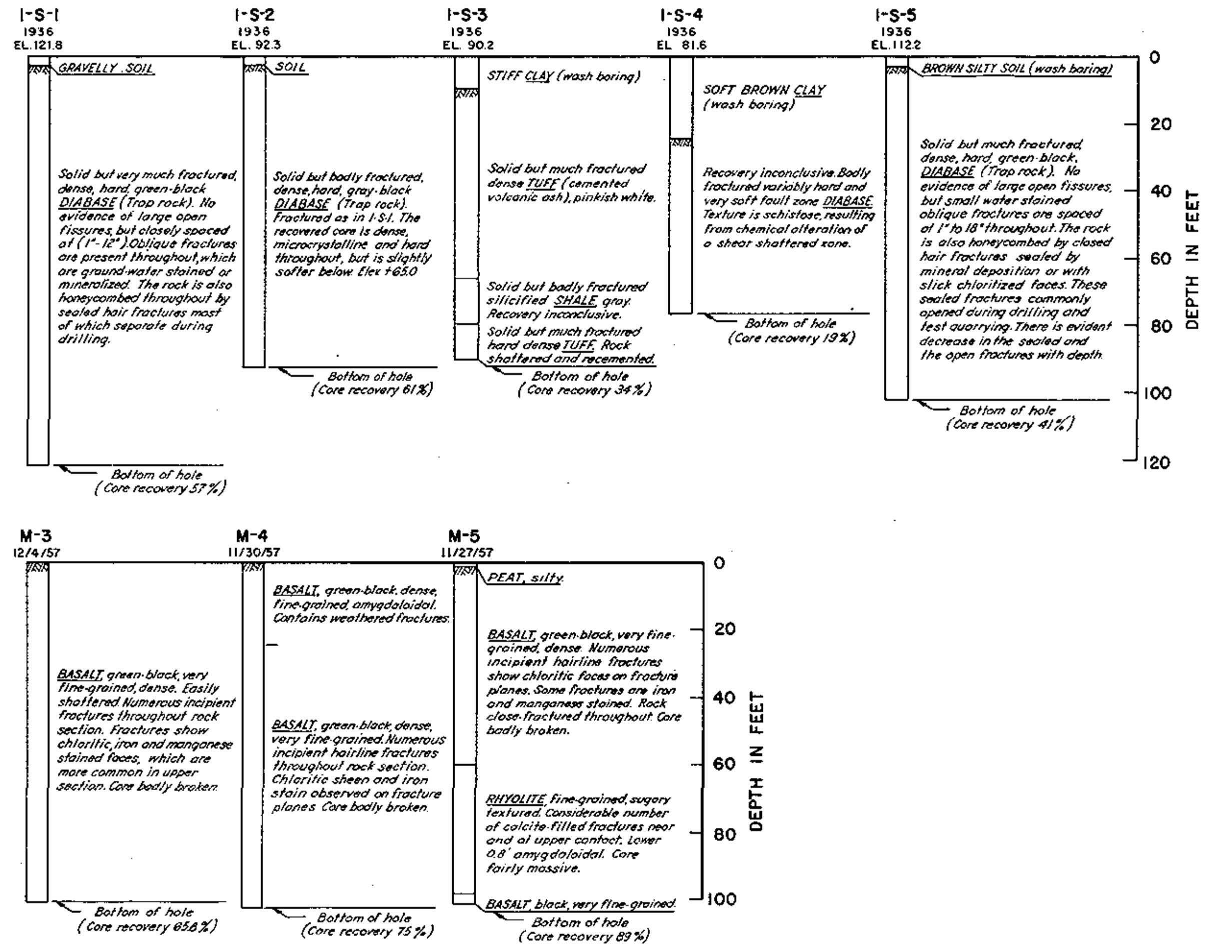
VICINITY MAP

SCALE IN MILES
1 0 1 2 3



PLAN

SCALE IN FEET
200 0 200 400



LEGEND

TS	*Topsoil*
GW	*Gravel or Sandy Grav. (well graded)*
GP	*Gravel or Sandy Grav. (poorly graded)*
GM	*Silty Gravel or Silty Sandy Gravel*
GC	*Clayey Grav. or Clayey Sandy Gravel*
SW	*Sand or Gravelly Sand (well graded)*
SP	*Sand or Gravelly Sand (poorly graded)*
SM	*Silty Sand or Silty Gravelly Sand*
SC	*Clayey Sand or Clayey Grav. Sand*
ML	*Silts, Sandy Silts, Grav. Silts or Diatomaceous Soils*
CL	*Lean Clays, Sandy Clays, Grav. Clays*
OL	*Organic Silts, Lean Organic Clays*
MH	*Micaceous Silts, Diatomaceous Soils or Elastic Silts*
CH	*Fat Clays*
OH	*Fat Organic Clays*
PT	*Peat, Humus and other Organic Soils*

SYMBOLS

● - *NX Diamond Drill Hole.*

NOTES

1 - *Exploration data for holes I-S-1 to I-S-5 incl., obtained from 1936 records.*

2 - *Soil designation of 1936 holes not standard classification.*

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

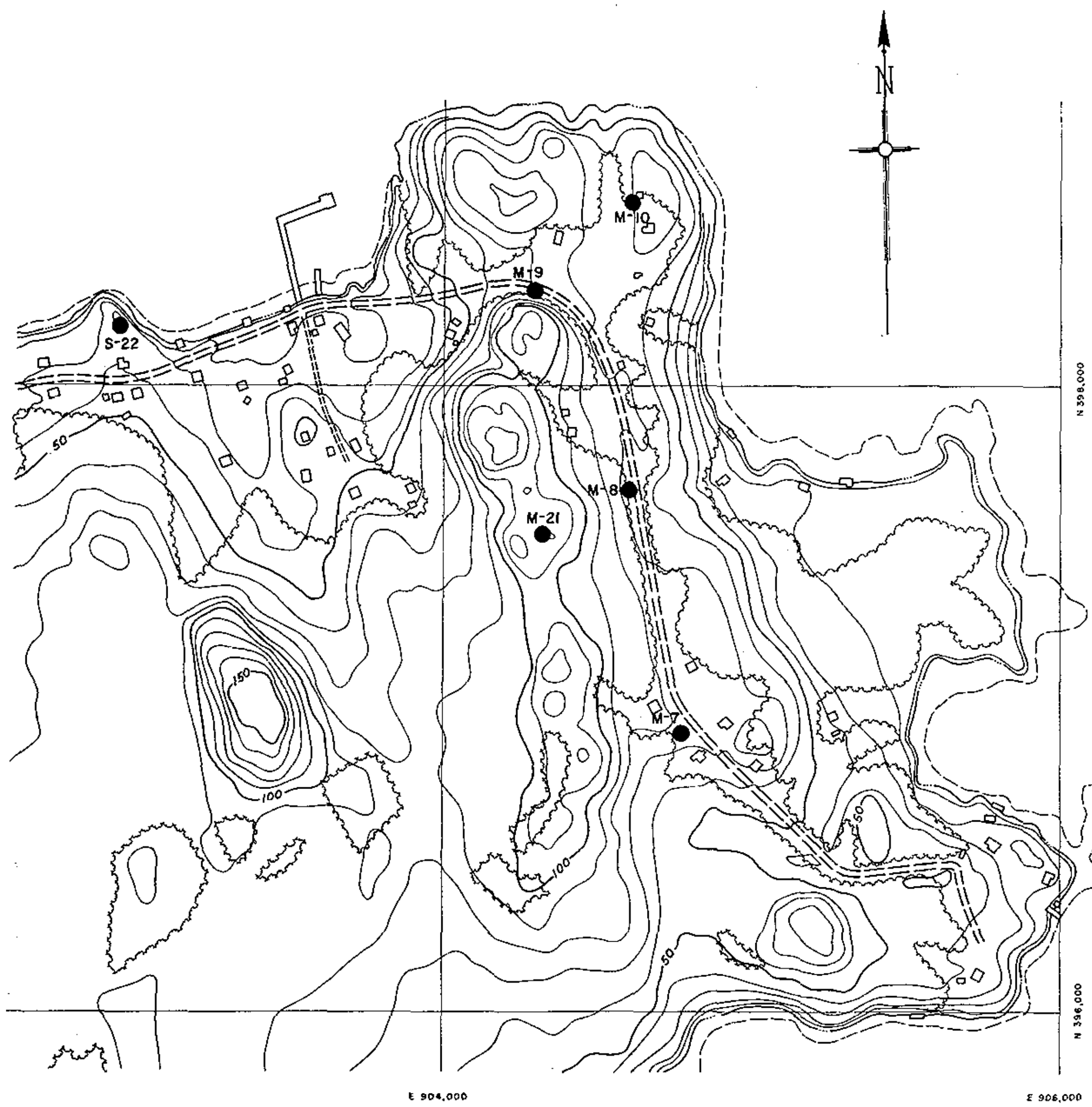
TIDAL PROJECT

SUBSURFACE EXPLORATIONS

SHACKFORD HEAD

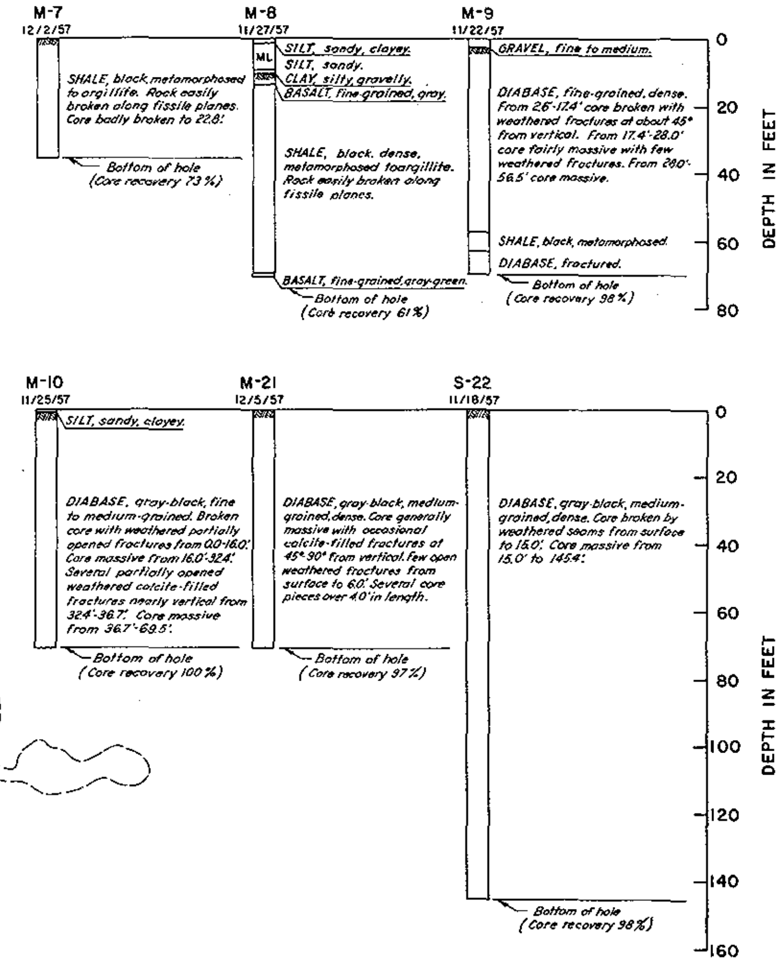
International Passamaquoddy Engineering Board

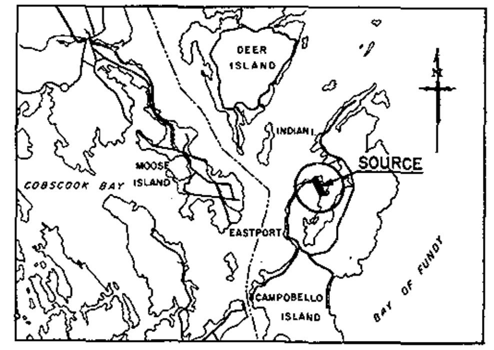
OCTOBER 1959 Dwg. No. TG7-118



PLAN

SCALE IN FEET
200 0 200 400





VICINITY MAP

SCALE IN MILES
1 0 1 2 3

LEGEND

TS	*Topsoil*
GW	*Gravel or Sandy Grav. (well graded)*
GP	*Gravel or Sandy Grav. (poorly graded)*
GM	*Silty Gravel or Silty Sandy Gravel*
GC	*Clayey Gravel or Clayey Sandy Gravel*
SW	*Sand or Gravelly Sand (well graded)*
SP	*Sand or Gravelly Sand (poorly graded)*
SM	*Silty Sand or Silty Gravelly Sand*
SC	*Clayey Sand or Clayey Grav. Sand*
ML	*Silts, Sandy Silts, Grav. Silts or Diatomaceous Soils*
CL	*Lean Clays, Sandy Clays, Grav. Clays*
OL	*Organic Silts, Lean Organic Clays*
MH	*Micaceous Silts, Diatomaceous soils or Elastic Silts*
CH	*Fat Clays*
OH	*Fat Organic Clays*
PT	*Peat, Humus and other Organic Soils*

SYMBOLS

● - *NX Diamond Drill Hole*

NOTES

1 - *Soil classification based on field examination.*

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

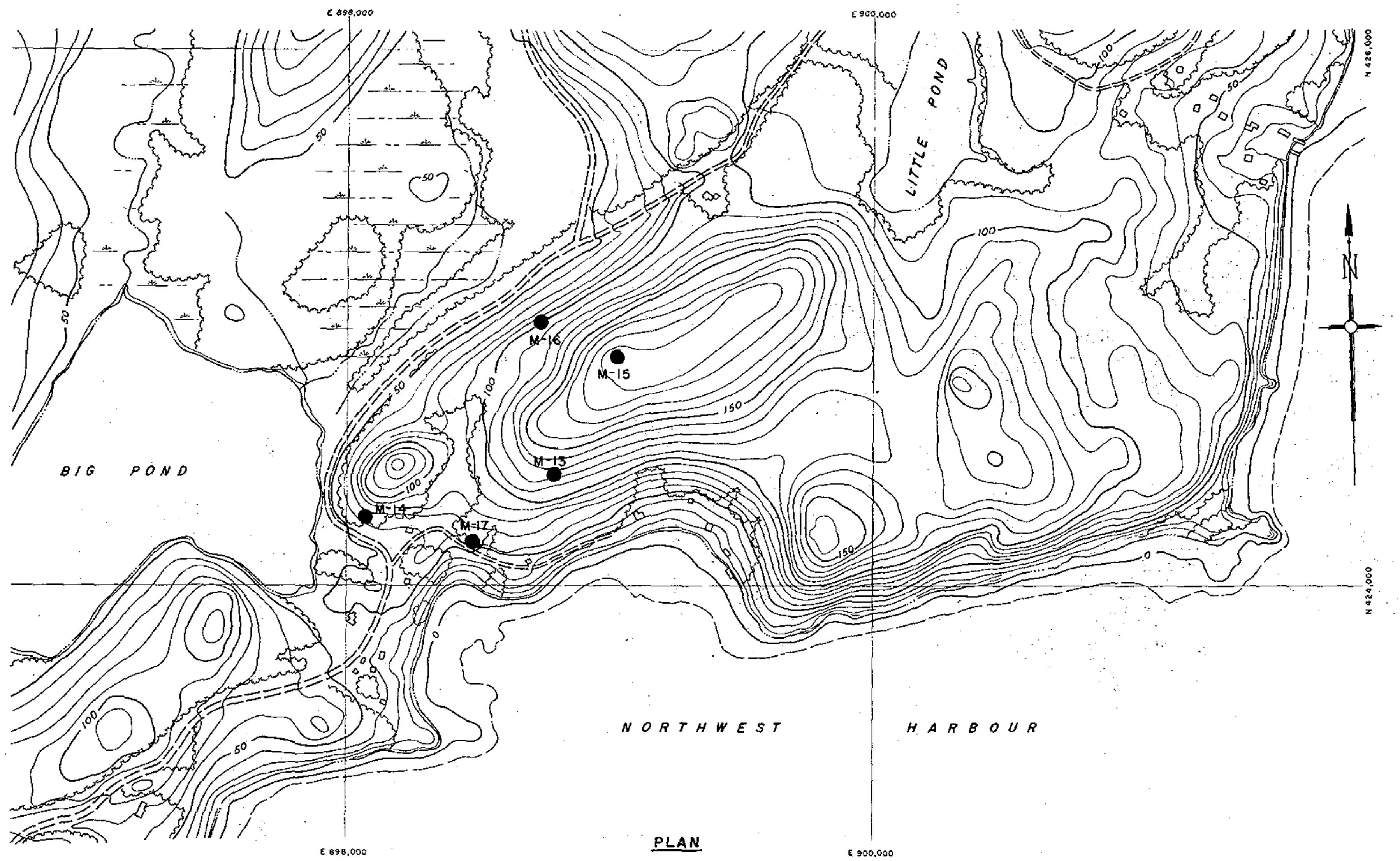
TIDAL PROJECT

SUBSURFACE EXPLORATIONS

MAN OF WAR HEAD

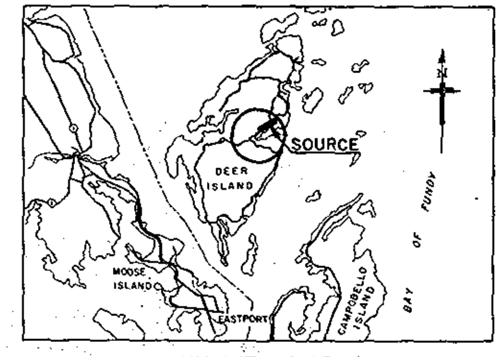
International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-119



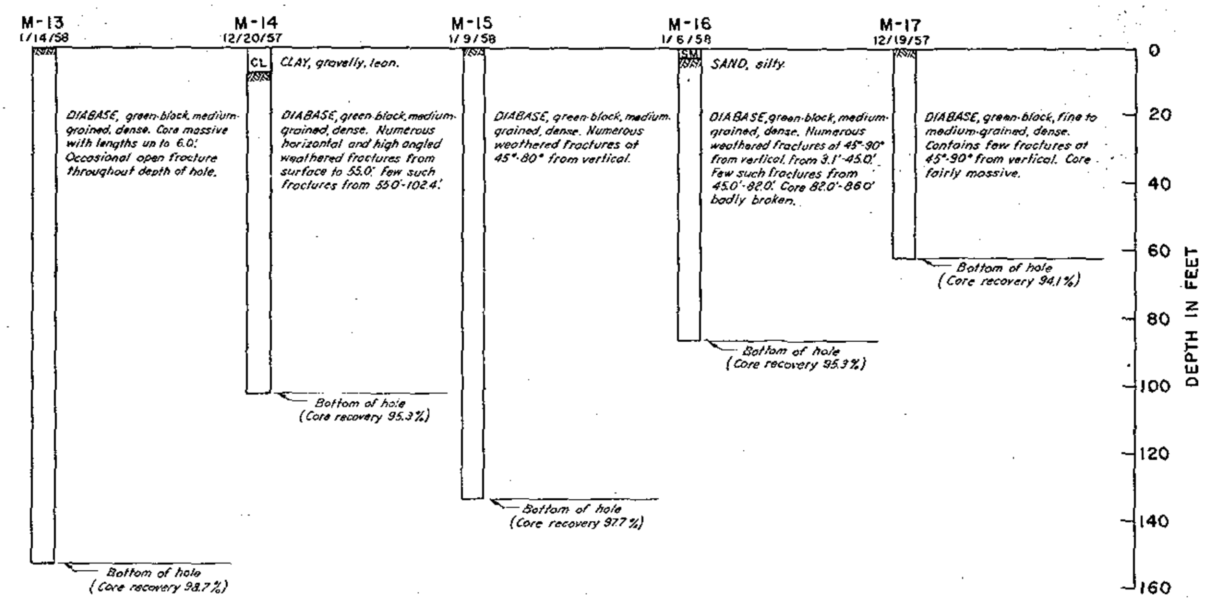
PLAN

SCALE IN FEET
200 0 200 400



VICINITY MAP

SCALE IN MILES
1 0 1 2 3



LEGEND

TS	*Topsoil*
GW	*Gravel or Sandy Grav. (well graded)*
GP	*Gravel or Sandy Grav. (poorly graded)*
GM	*Silty Gravel or Silty Sandy Gravel*
GC	*Clayey Grav. or Clayey Sandy Gravel*
SW	*Sand or Gravelly Sand (well graded).*
SP	*Sand or Gravelly Sand (poorly graded)*
SM	*Silty Sand or Silty Gravelly Sand*
SC	*Clayey Sand or Clayey Grav. Sand*
ML	*Silts, Sandy Silts, Grav. Silts or Diatomaceous Soils*
CL	*Lean Clays, Sandy Clays, Grav. Clays*
OL	*Organic Silts, Lean Organic Clays*
MH	*Micaceous Silts, Diatomaceous Soils or Elastic Silts*
CH	*Fat Clays*
OH	*Fat Organic Clays*
PT	*Peat, Humus and other Organic Soils*

SYMBOLS

● - *NX Diamond Drill Hole.*

NOTES

Soil classification based on field examination.

Elevations are in feet, m.s.l.

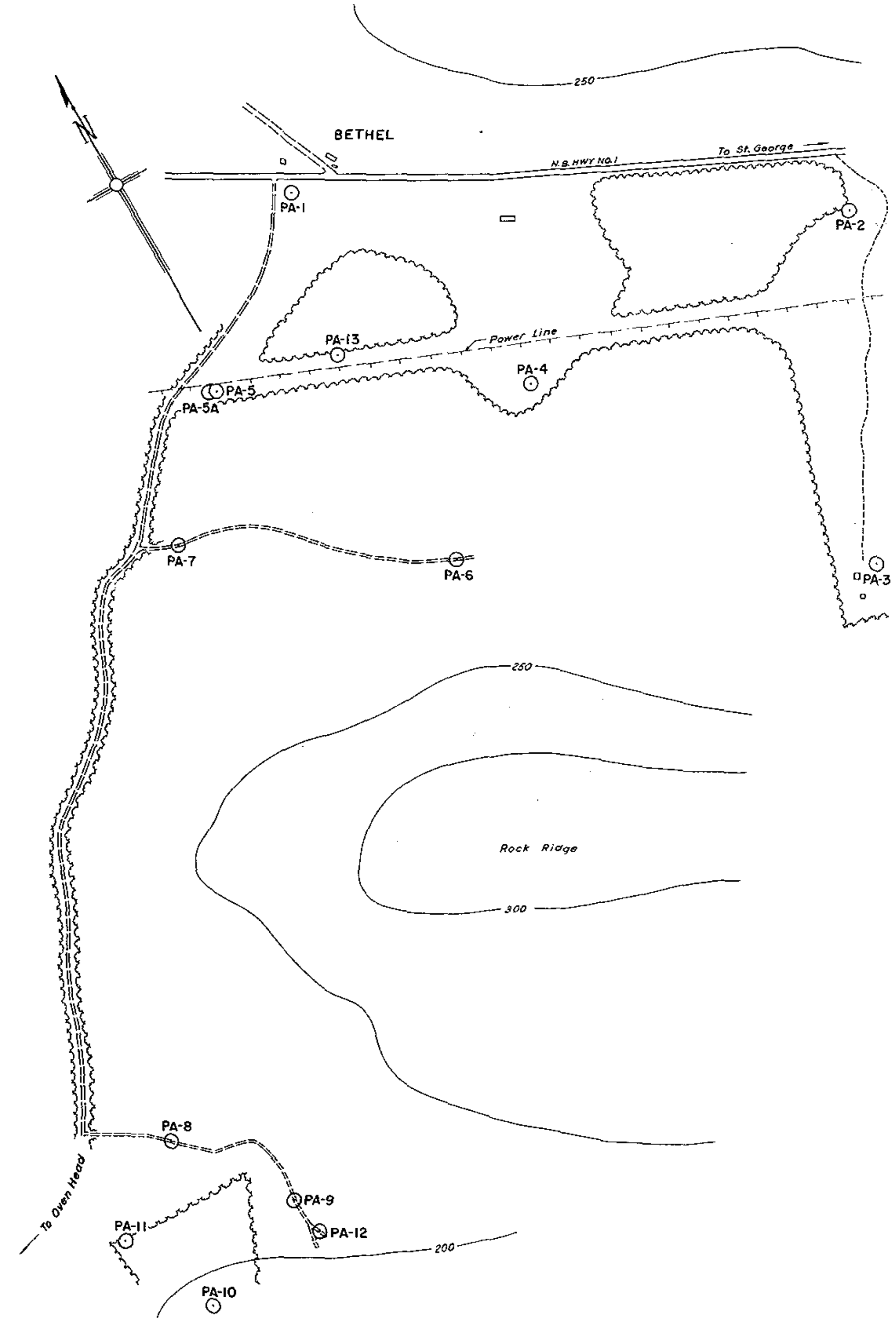
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT
SUBSURFACE EXPLORATIONS
NORTHWEST HARBOUR

International Passamaquoddy Engineering Board

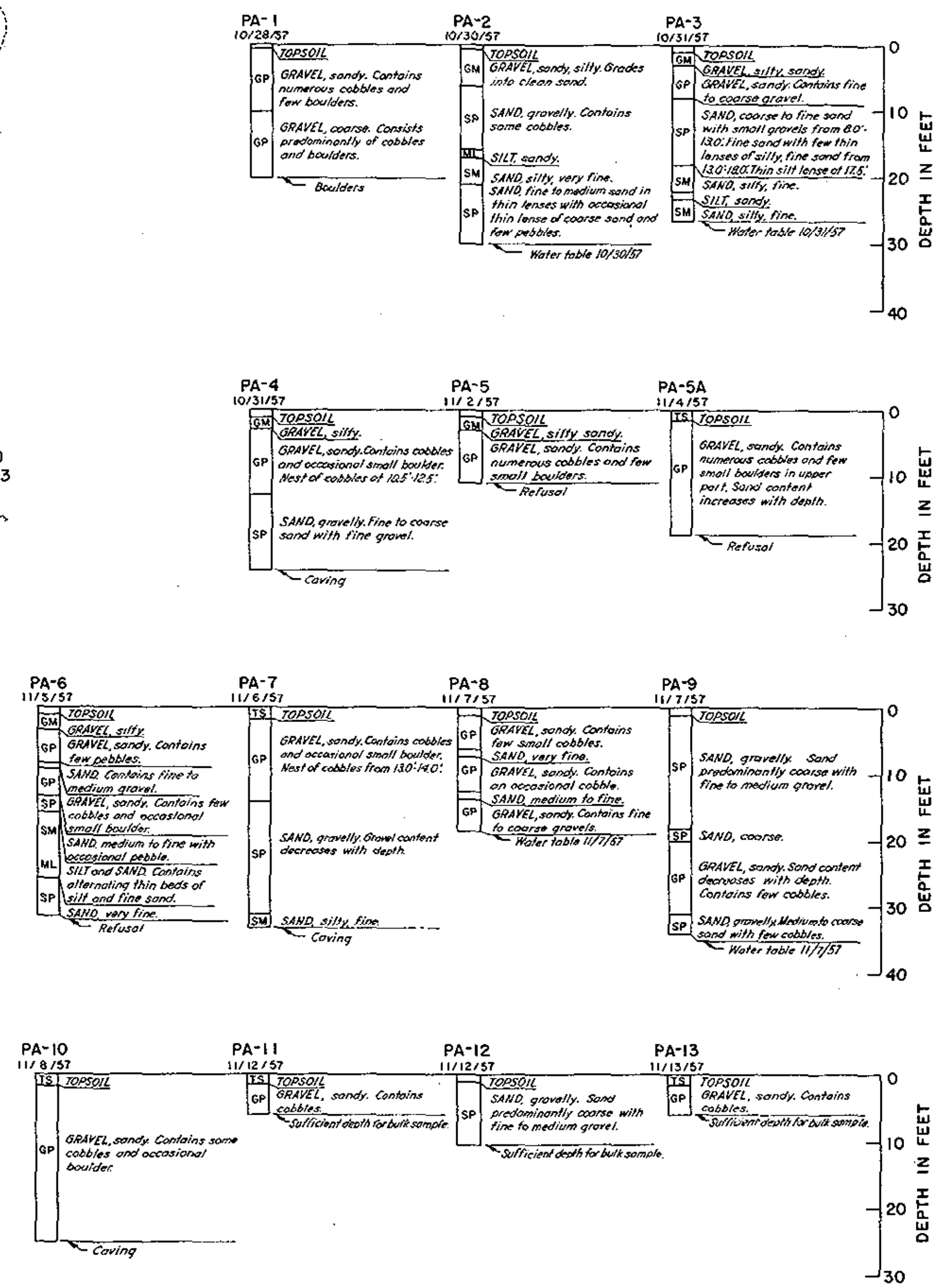
OCTOBER 1959

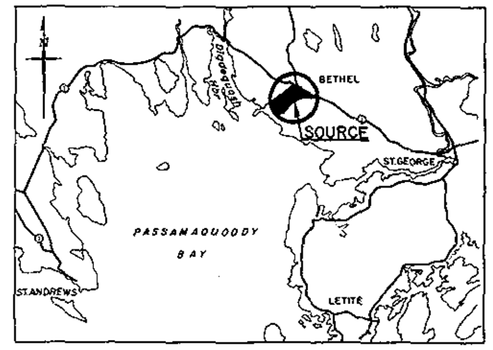
Dwg. No. TG7-120



PLAN

SCALE IN FEET
200 0 200 400





VICINITY MAP

SCALE IN MILES
1 0 1 2 3

LEGEND

TS	Topsoil.
GW	Gravel or Sandy Grav. (well graded).
GP	Gravel or Sandy Grav. (poorly graded).
GM	Silty Grav. or Silty Sandy Gravel.
GC	Clayey Grav. or Clayey Sandy Gravel.
SW	Sand or Gravelly Sand (well graded).
SP	Sand or Gravelly Sand (poorly graded).
SM	Silty Sand or Silty Gravelly Sand.
SC	Clayey Sand or Clayey Grav. Sand.
ML	Silts, Sandy Silts, Grav. Silts, or Diatomaceous Soils.
CL	Lean Clays, Sandy Clays, Grav. Clays.
OL	Organic Silts, Lean Organic Clays.
MH	Micaceous Silts, Diatomaceous Soils or Elastic Silts.
CH	Fat Clays.
OH	Fat Organic Clays.
PT	Peat, Humus and other Organic Soils.

SYMBOLS

⊙ PA - Power Auger Boring

NOTES

1 - Soil classification based on field examination.

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

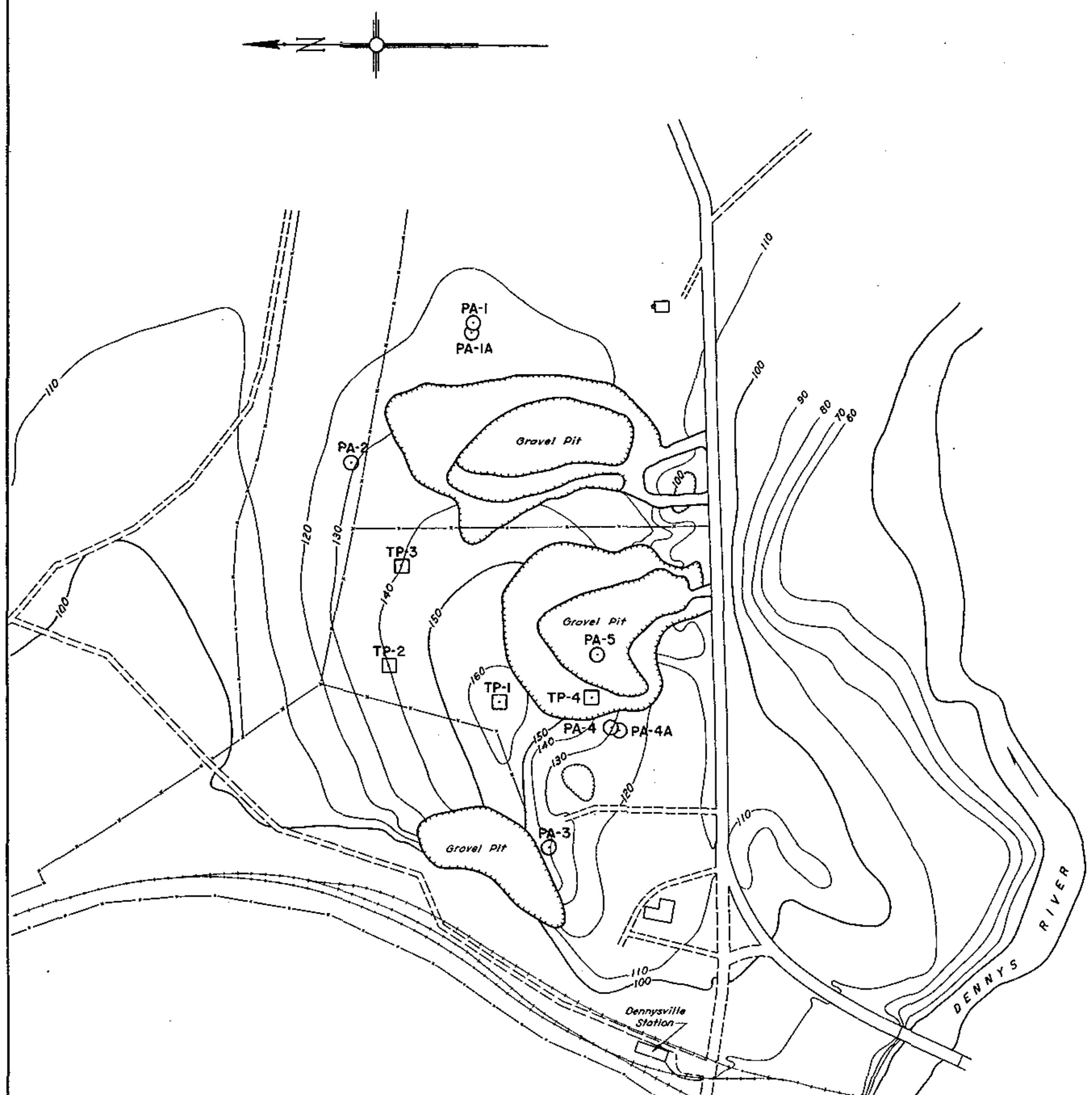
SUBSURFACE EXPLORATIONS

BETHEL TERRACE

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-121

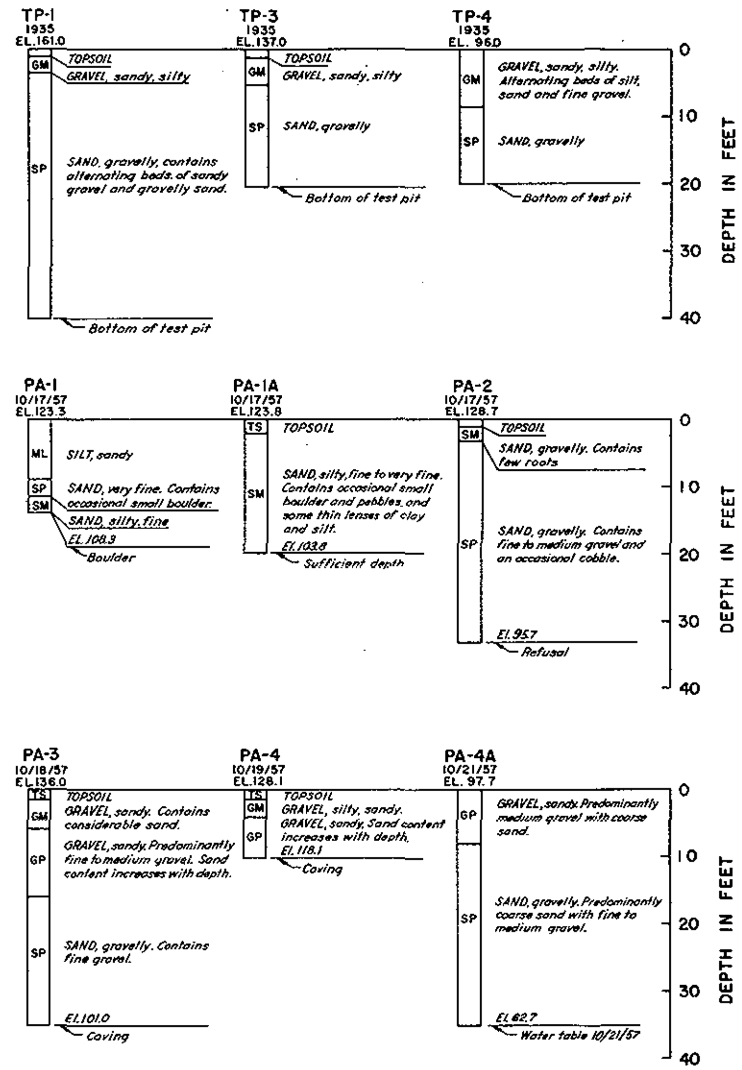
PLATE 2-9

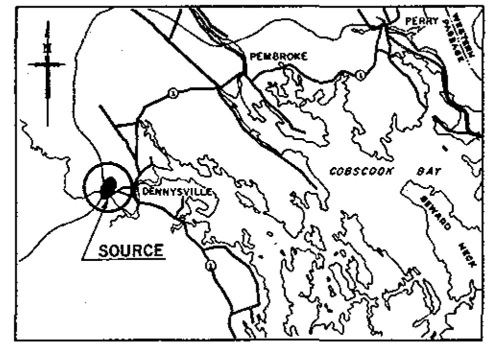


PLAN

SCALE IN FEET

100 0 100 200 300





VICINITY MAP

SCALE IN MILES

1 0 1 2 3

LEGEND

TS	*Topsoil*
GW	*Gravel or Sandy Grav. (well graded)*
GP	*Gravel or Sandy Grav. (poorly graded)*
GM	*Silty Gravel or Silty Sandy Gravel*
GC	*Clayey Grav. or Clayey Sandy Gravel*
SW	*Sand or Gravelly Sand (well graded)*
SP	*Sand or Gravelly Sand (poorly graded)*
SM	*Silty Sand or Silty Gravelly Sand*
SC	*Clayey Sand or Clayey Grav. Sand*
ML	*Silts, Sandy Silts, Grav. Silts or Diatomaceous Soils*
CL	*Lean Clays, Sandy Clays, Grav. Clays*
OL	*Organic Silts, Lean Organic Clays*
MH	*Micaceous Silts, Diatomaceous Soils or Elastic Silts*
CH	*Fat Clays*
OH	*Fat Organic Clays*
PT	*Peat, Humus and other Organic Soils*

SYMBOLS

⊙ PA = *Power Auger Boring*

⊡ TP = *Test Pit*

NOTES

1 - *Soil classification based on field examination.*

2 - *Topographic information taken from Passamaquoddy Tidal Power Development Sheet No. Q-S-10/28, dated Oct. 1935.*

3 - *Test Pits Nos. 1, 3 and 4, exploration performed in 1935. No record of Test Pit No.2 available.*

4 - *PA-4 stopped at shallow depth because of caving.*

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

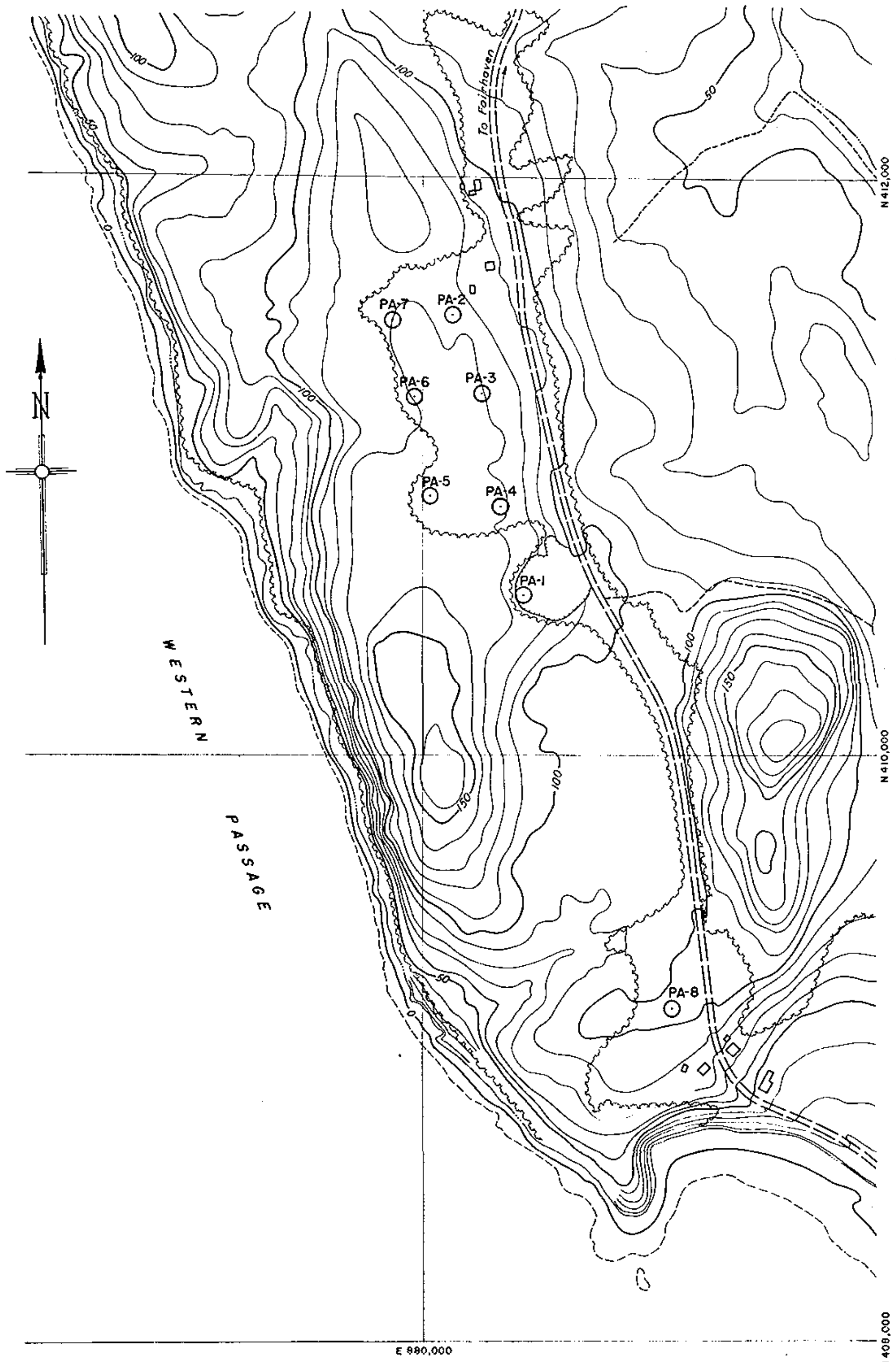
TIDAL PROJECT

SUBSURFACE EXPLORATIONS

DENNYSVILLE

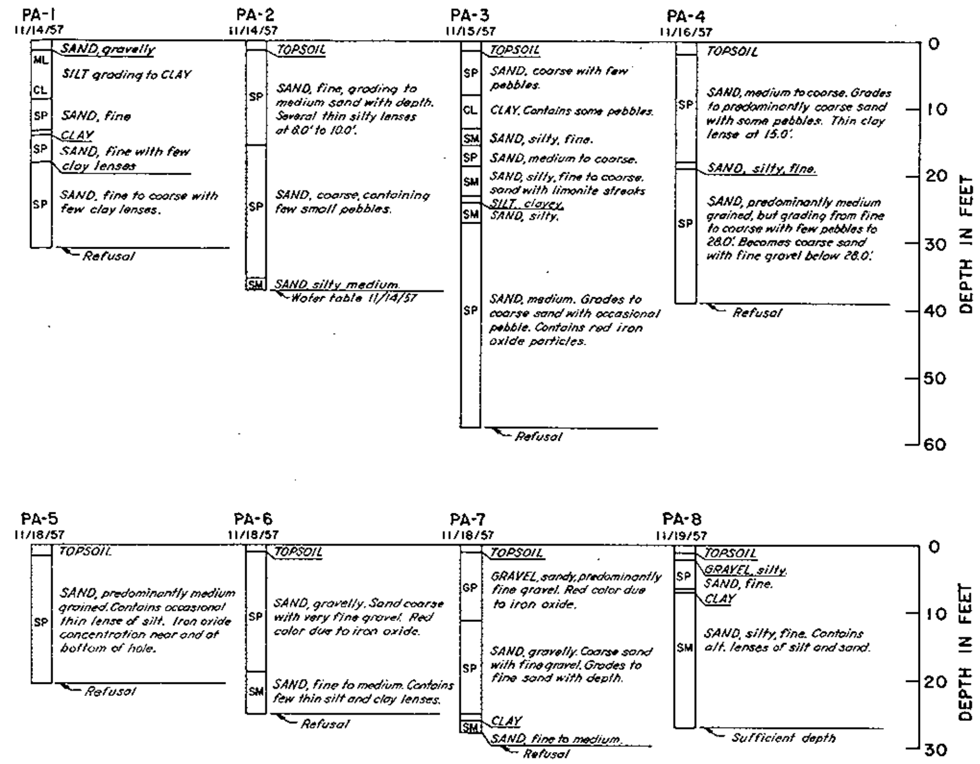
International Passamaquoddy Engineering Board

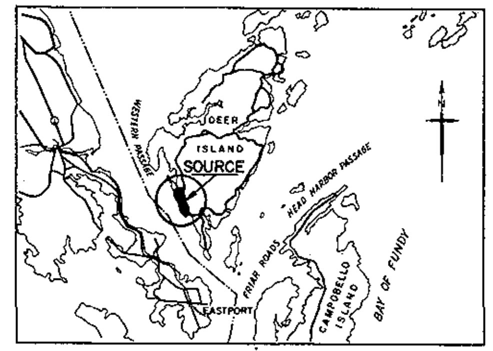
OCTOBER 1959 Dwg. No. TG7-122



PLAN

SCALE IN FEET
200 0 200 400





VICINITY MAP

SCALE IN MILES
1 0 1 2 3

LEGEND

TS	*Topsoil*
GW	*Gravel or Sandy Grav. (well graded)*
GP	*Gravel or Sandy Grav. (poorly graded)*
GN	*Silty Grav. or Silty Sandy Gravel*
GC	*Clayey Grav. or Clayey Sandy Gravel*
SW	*Sand or Gravelly Sand (well graded)*
SP	*Sand or Gravelly Sand (poorly graded)*
SM	*Silty Sand or Silty Gravelly Sand*
SC	*Clayey Sand or Clayey Grav. Sand*
ML	*Silts, Sandy Silts, Grav. Silts, or Diatomaceous Soils*
CL	*Lean Clays, Sandy Clays, Grav. Clays*
OL	*Organic Silts, Lean Organic Clays*
MH	*Micaceous Silts, Diatomaceous Soils or Elastic Silts*
CH	*Fat Clays*
OH	*Fat Organic Clays*
PT	*Peat, Humus and other Organic Soils*

SYMBOLS

⊙ PA = *Power Auger Boring*

NOTES

1 - *Soil classification based on field examination.*

2 - *Contours are based on M.S.L.*

Elevations are in feet, m.s.l.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

SUBSURFACE EXPLORATIONS

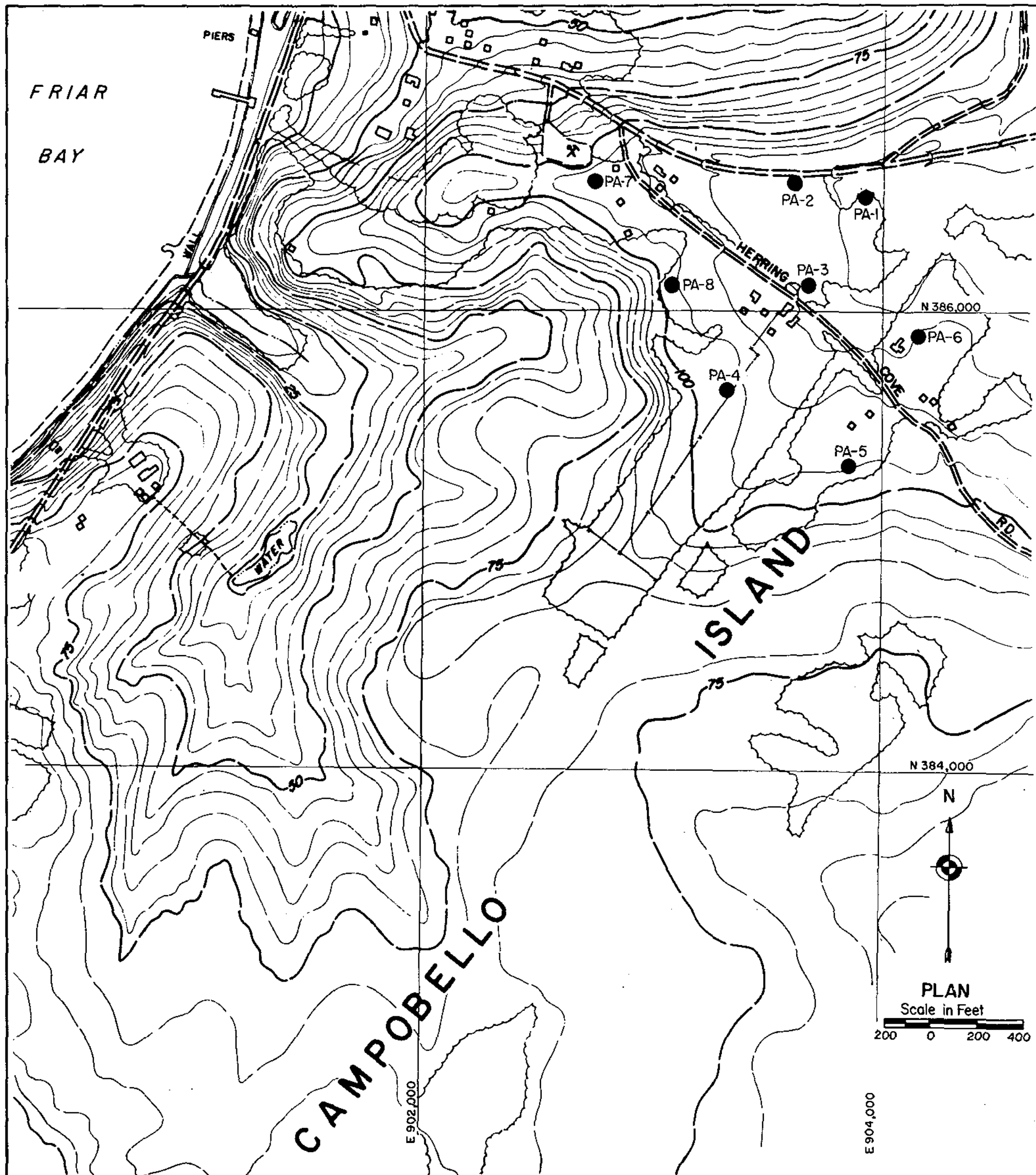
CUMMINGS COVE

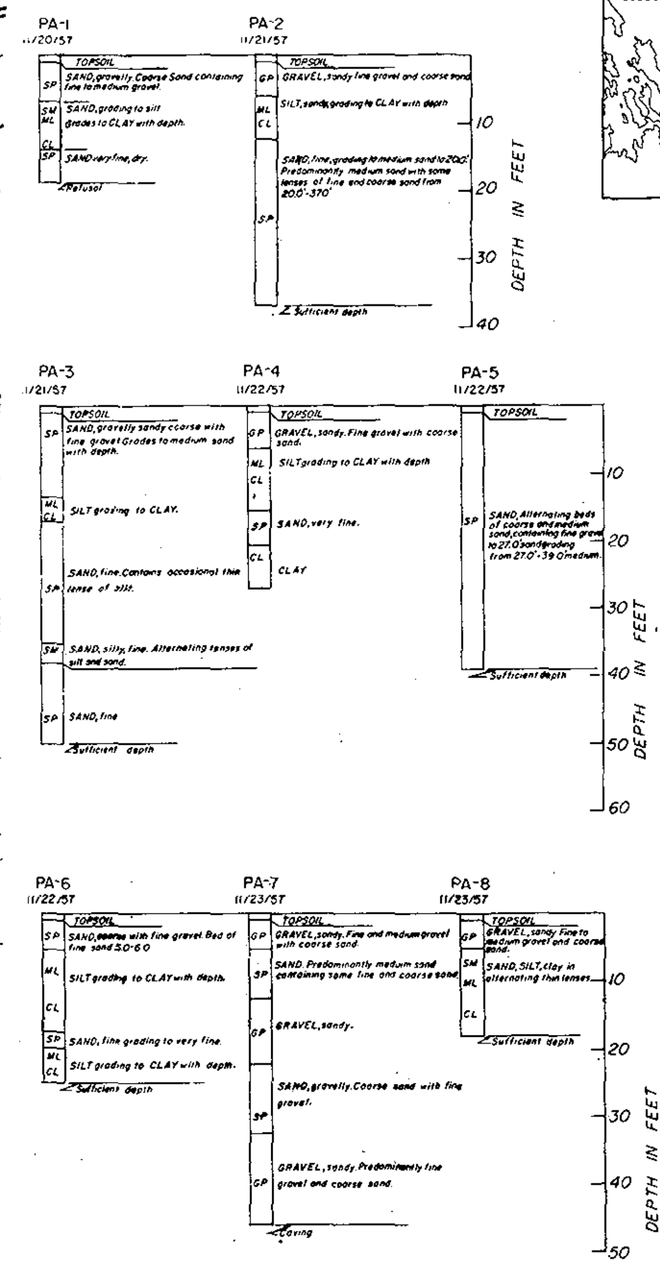
International Passamaquoddy Engineering Board

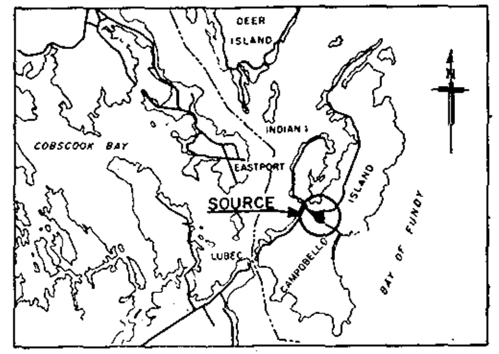
OCTOBER 1959

Dwg. No. TG7-123

PLATE 2-11







VICINITY MAP

SCALE IN MILES

1 0 1 2 3

LEGEND

TS	Topsoil.
GW	Gravel or Sandy Grav. (well graded).
GP	Gravel or Sandy Grav. (poorly graded).
GM	Silty Grav. or Silty Sandy Gravel.
GC	Clayey Grav. or Clayey Sandy Gravel.
SW	Sand or Gravelly Sand (well graded).
SP	Sand or Gravelly Sand (poorly graded).
SM	Silty Sand or Silty Gravelly Sand.
SC	Clayey Sand or Clayey Grav. Sand.
ML	Silts, Sandy Silts, Grav. Silts, or Diatomaceous Soils.
CL	Lean Clays, Sandy Clays, Grav. Clays.
OL	Organic Silts, Lean Organic Clays.
MH	Micaceous Silts, Diatomaceous Soils or Elastic Silts.
CH	Fat Clays.
OH	Fat Organic Clays.
PT	Peat, Humus and other Organic Soils.

SYMBOLS

⊕ PA = POWER AUGER BORINGS

NOTES

1. Soil Classification based on field examination.
2. Contours are based on M.S.L.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

SUBSURFACE EXPLORATIONS

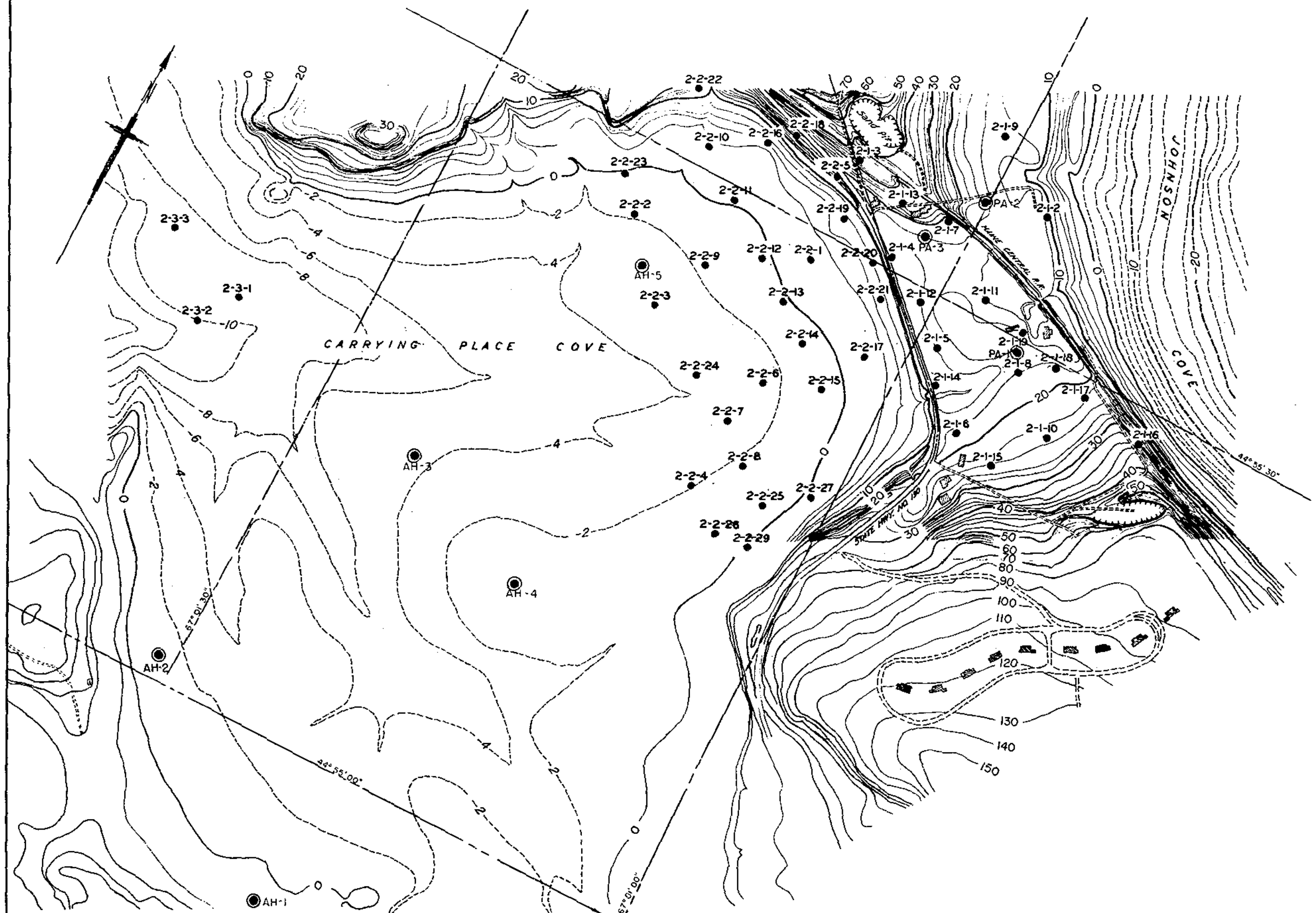
WELSHPOOL

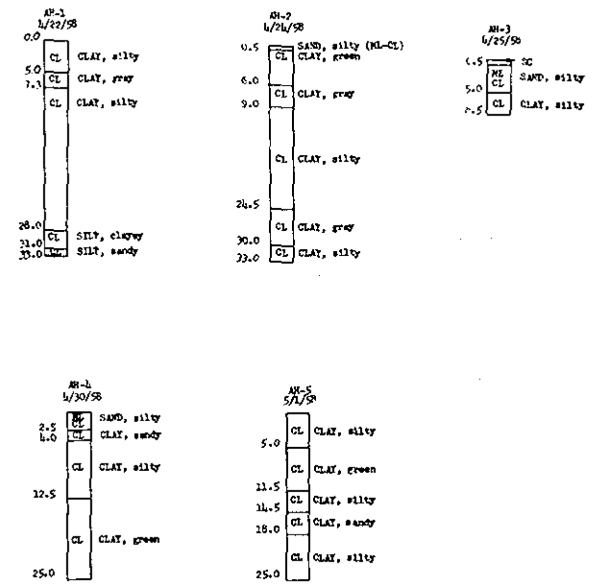
International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-124

PLATE 2-12

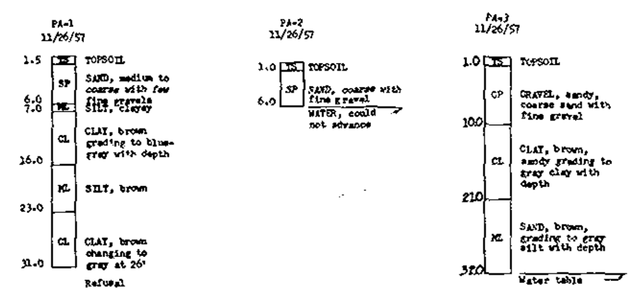




NOTE:
For record of exploration 1935 borings, see plates 2-14, 2-15, and 2-16.

LEGEND
● 1935 exploration
◉ 1958 exploration

BORING PLAN



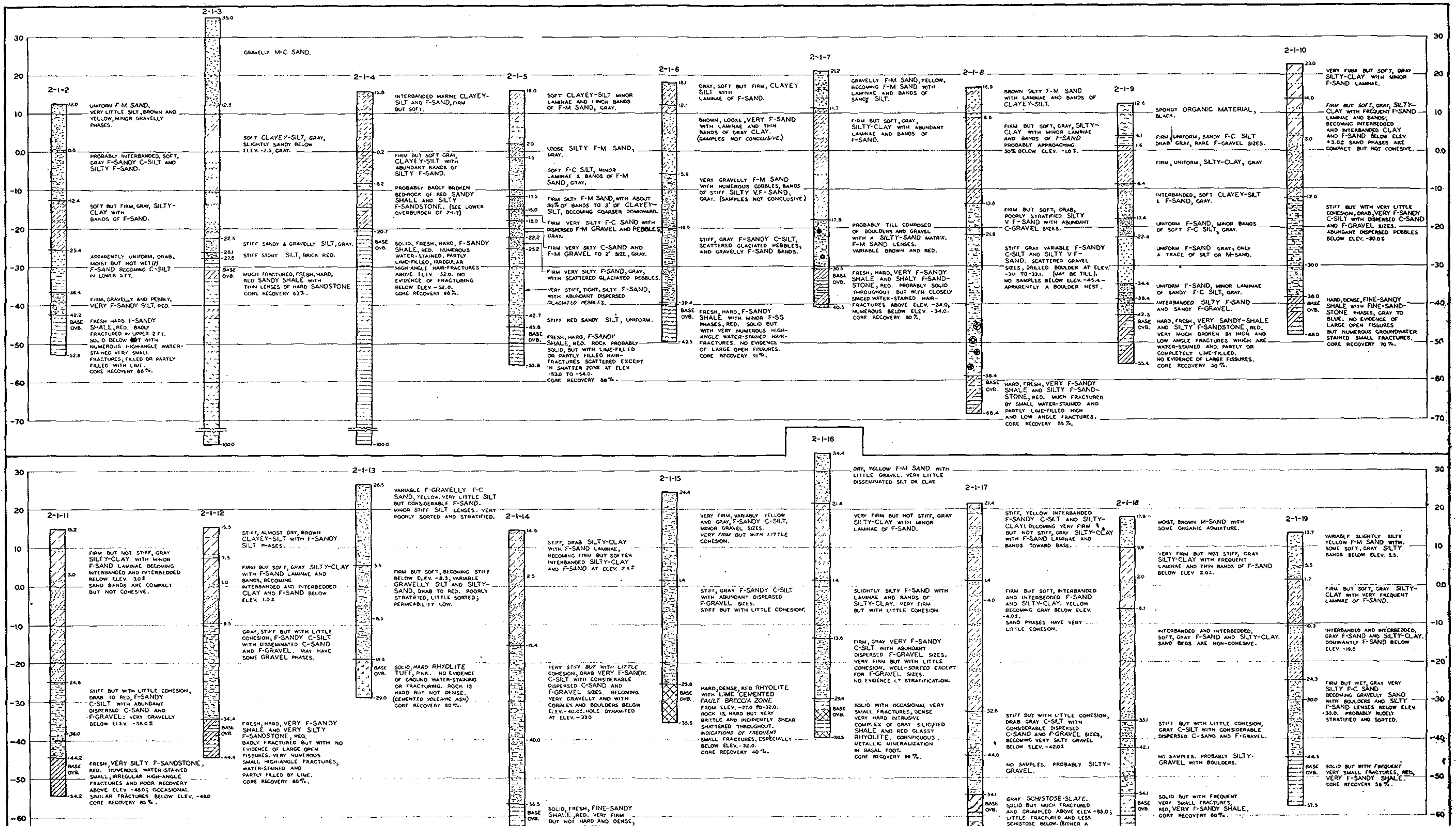
SCALE IN FEET
200' 0 200' 400'

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT
BORING PLAN, 1935~CARRYINGPLACE COVE

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-125



LEGEND

BASE OVB. INDICATES BASE OF OVERBURDEN.
F INDICATES FINE-GRAINED.
M INDICATES MEDIUM-GRAINED.
C INDICATES COARSE-GRAINED.
ELEVATION OF BASE OF OVERBURDEN IS EXACT. ALL OTHER CONTACTS ARE CLOSELY APPROXIMATE.

NOTE:- ELEVATIONS IN FEET MEAN SEA LEVEL. FOR LOCATION OF BORINGS SHOWN ON THIS SHEET, SEE PLATE NO. 2-13.

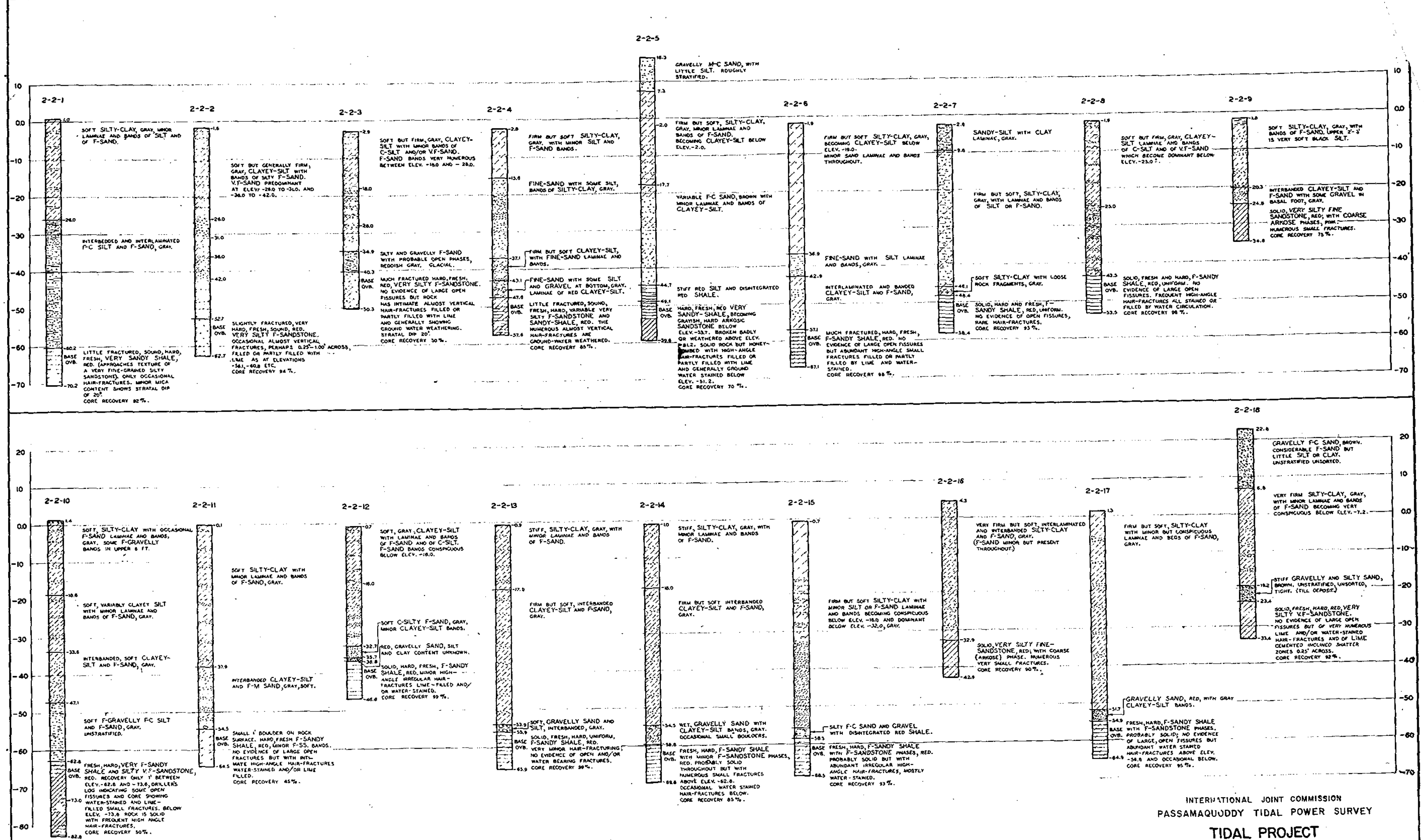
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

RECORD OF EXPLORATION, 1935
BORINGS AT CARRYINGPLACE COVE, SHEET I

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-126



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

RECORD OF EXPLORATION, 1935

BORINGS AT CARRYINGPLACE COVE, SHEET 2

International Passamaquoddy Engineering Board

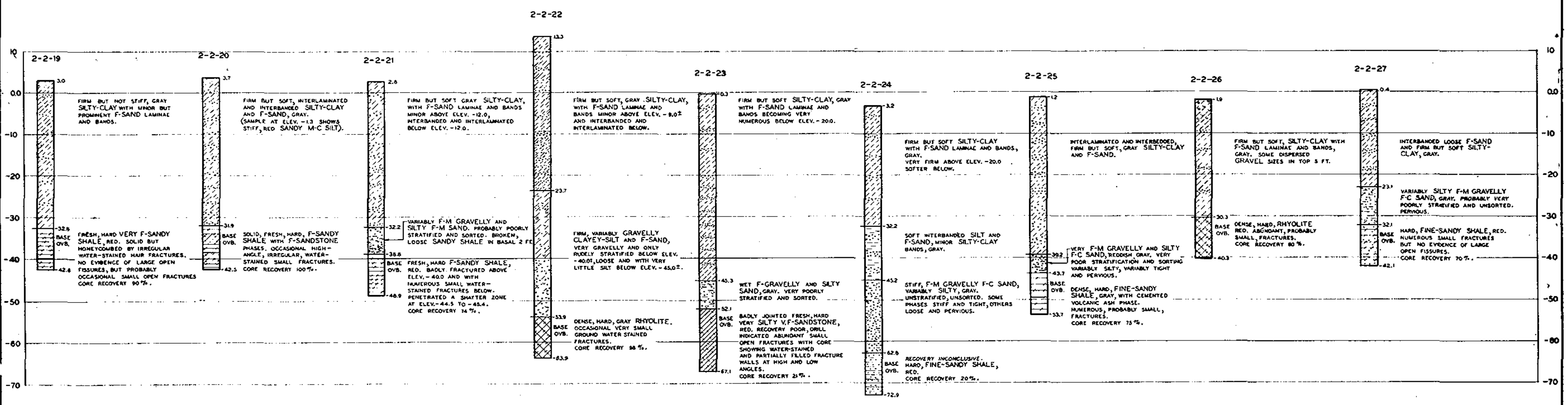
OCTOBER 1959

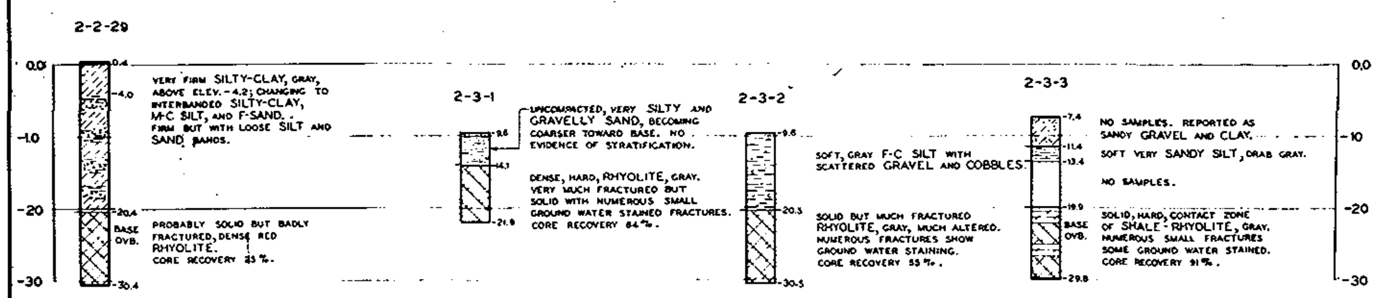
Dwg. No. TG7-127

LEGEND

BASE OVB. INDICATES BASE OF OVERBURDEN.
F INDICATES FINE-GRAINED.
M INDICATES MEDIUM-GRAINED.
C INDICATES COARSE-GRAINED.
ELEVATION OF BASE OF OVERBURDEN IS EXACT. ALL OTHER CONTACTS ARE CLOSELY APPROXIMATE.

NOTE:- ELEVATIONS IN FEET MEAN SEA LEVEL.
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET, SEE PLATE NO. 2-13.





LEGEND

BASE OVB. INDICATES BASE OF OVERBURDEN.
F INDICATES FINE-GRAINED.
M INDICATES MEDIUM-GRAINED.
C INDICATES COARSE-GRAINED.
ELEVATION OF BASE OF OVERBURDEN IS EXACT. ALL OTHER CONTACTS ARE CLOSELY APPROXIMATE.

NOTE:- ELEVATIONS IN FEET MEAN SEA LEVEL.
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET, SEE PLATE NO.2-13

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

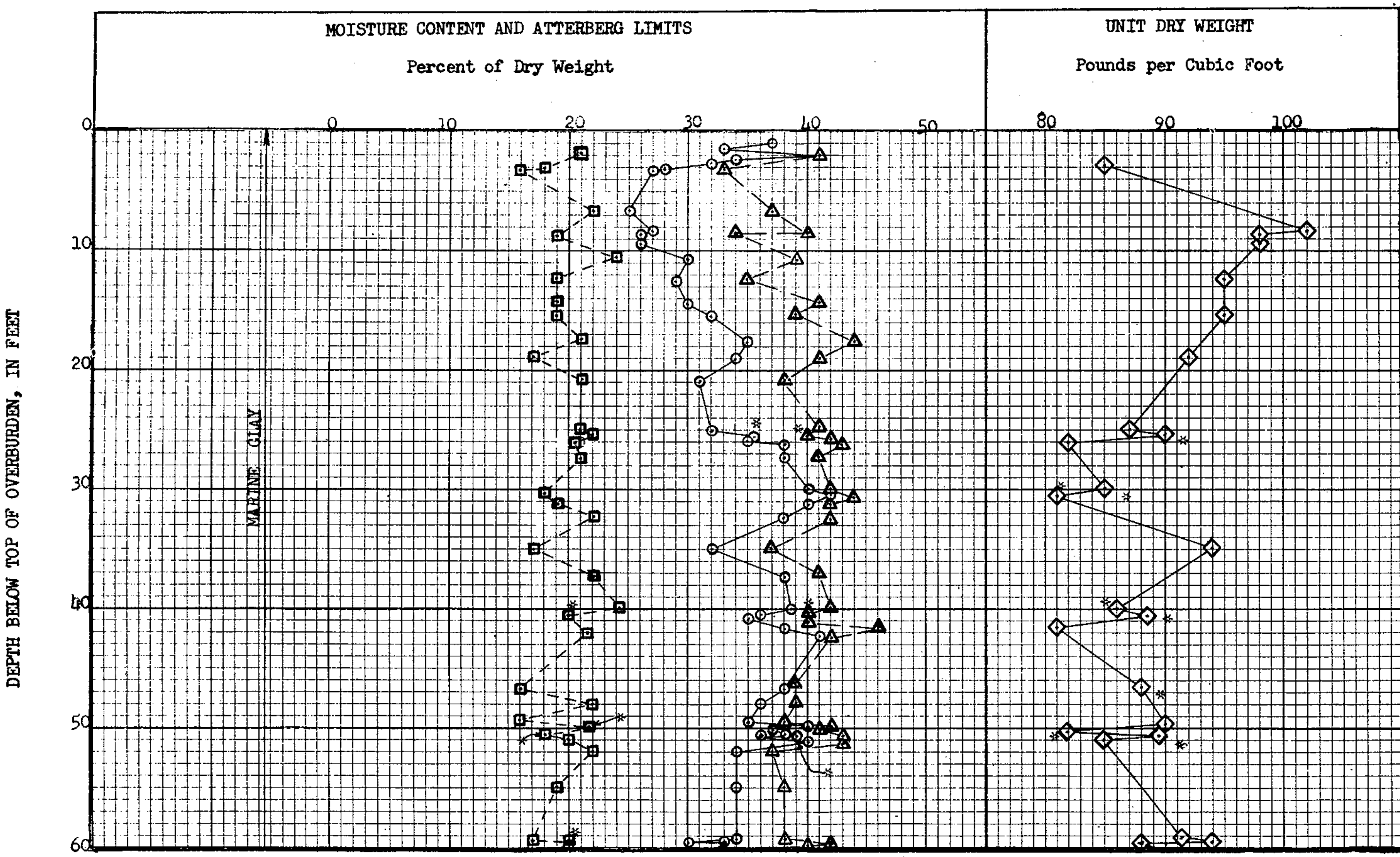
RECORD OF EXPLORATION, 1935

BORINGS AT CARRYINGPLACE COVE, SHEET 3

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-128

JOHNSON BAY



SHEAR STRENGTH				
CDD c / ø tsf/deg	CUT c / ø tsf/deg	UUT s tsf	UC-U $0.5q_u$ tsf	UC-R $0.5q_r$ tsf
.41/20.1			1.16*	0.38
			0.57	
			0.47	
			0.60*	0.070
.04/23.5	.31/11.4	0.41	0.42	
			0.29*	
			0.33*	
.00/26.6	.00/15.5	0.25	0.30*	
			0.29*	0.07
			0.30*	
.22/20.8	.00/20.3	0.21	0.24	
			0.38*	

LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -58.5 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

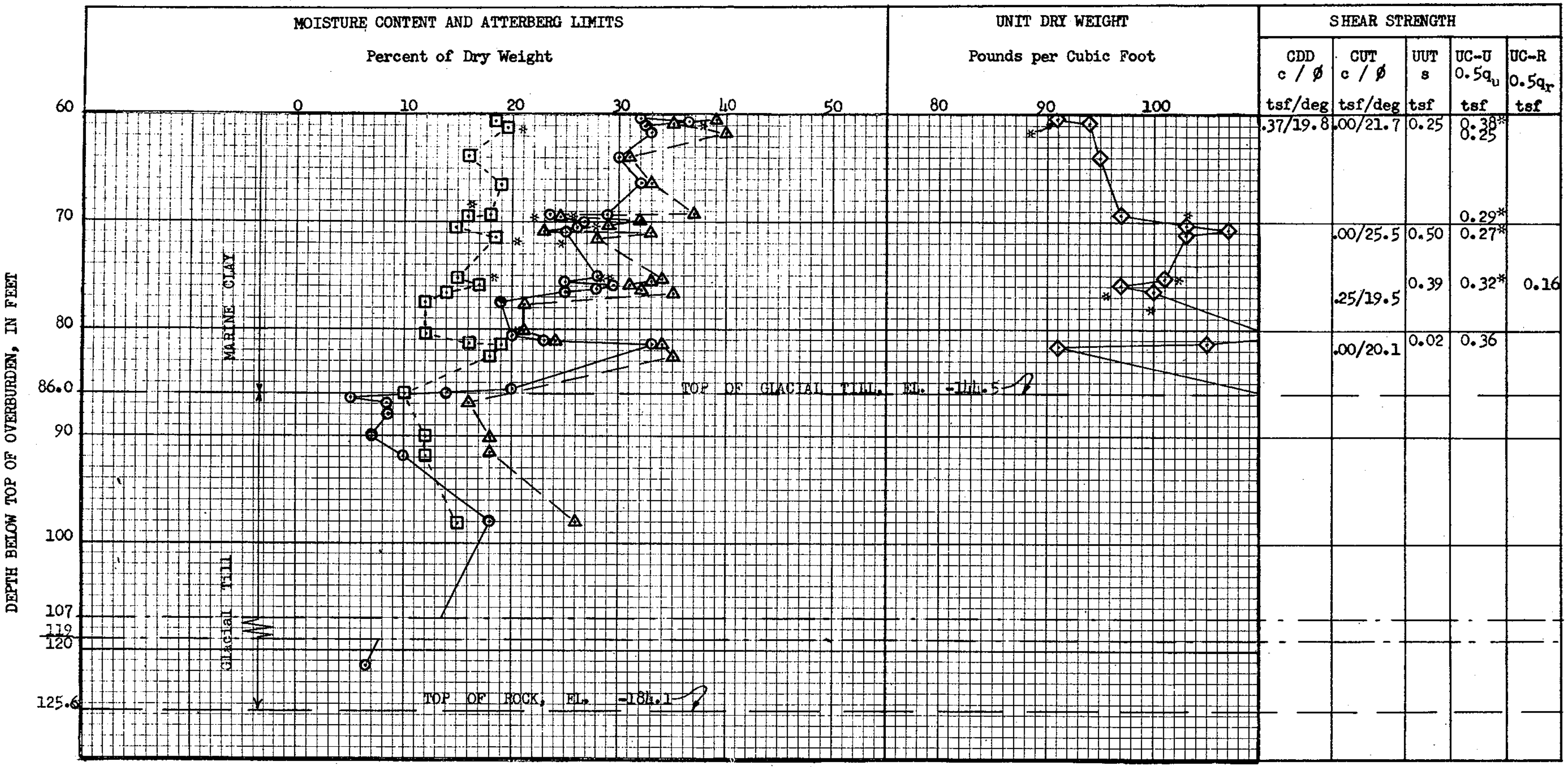
SOILS TEST DATA

BORING 101-D, SHEET 1

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-288

JOHNSON BAY



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -58.5 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

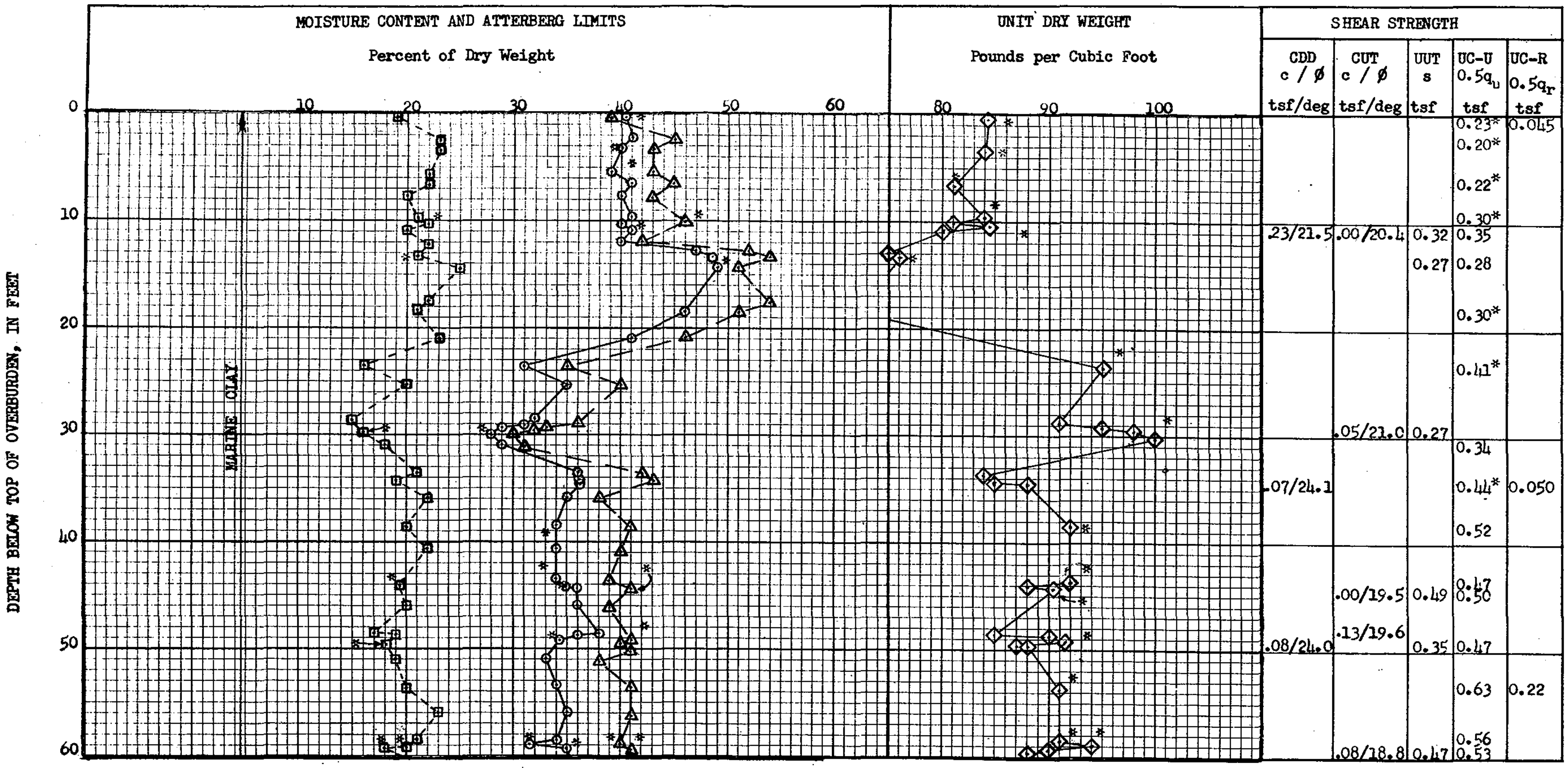
SOILS TEST DATA

BORING 101-D, SHEET 2

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-289

EASTPORT CHANNEL



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- **CDD** Consolidated-drained direct shear test
- **CUT** Consolidated-undrained triaxial compression test
- **UUT** Unconsolidated-undrained triaxial compression test
- **UC-U** Unconfined compression test - undisturbed soil
- **UC-R** Unconfined compression test - remolded soil

NOTES
Top of overburden el. -116.6 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

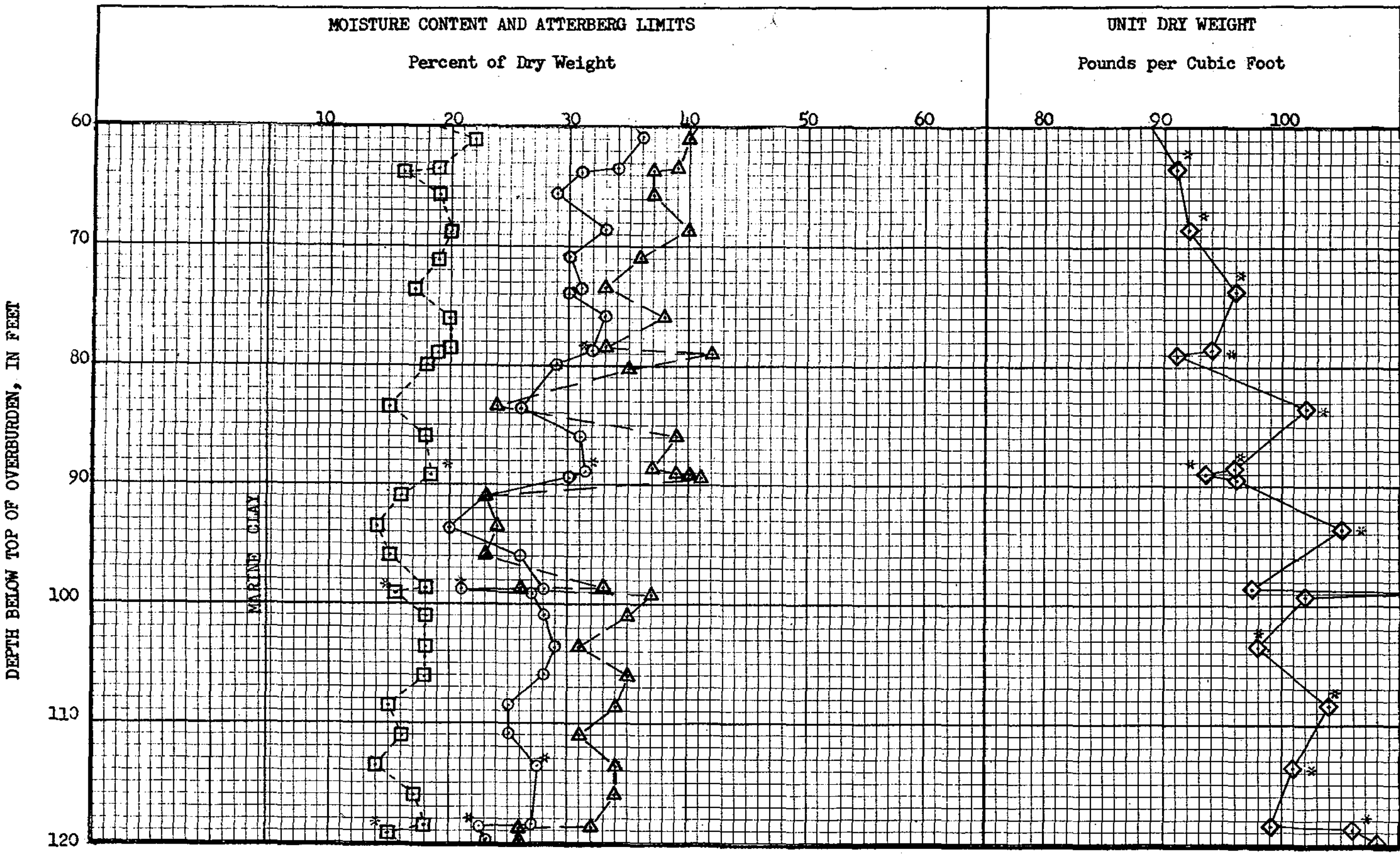
SOILS TEST DATA

BORING 102-D, SHEET 1

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-290

EASTPORT CHANNEL



SHEAR STRENGTH				
CDD c / Ø tsf/deg	CUT c / Ø tsf/deg	UUT s tsf	UC-U 0.5q_u tsf	UC-R 0.5q_r tsf
			0.55	
			0.48*	
			0.46*	
			0.51*	0.070
			0.40*	
			0.31*	
			0.51*	
	.05/27.8	0.45	0.45	
			0.32*	0.12
	.00/27.0	0.42	0.44	
			0.44	
			0.75	
			0.57	0.14
	.37/18.8	0.37	0.38	

LEGEND
⊡ Plastic Limit
⊙ Moisture Content
△ Liquid Limit
◇ Unit Dry Weight

TEST DESIGNATIONS
CDD Consolidated-drained direct shear test
CUT Consolidated-undrained triaxial compression test
UUT Unconsolidated-undrained triaxial compression test
UC-U Unconfined compression test - undisturbed soil
UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -116.6 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

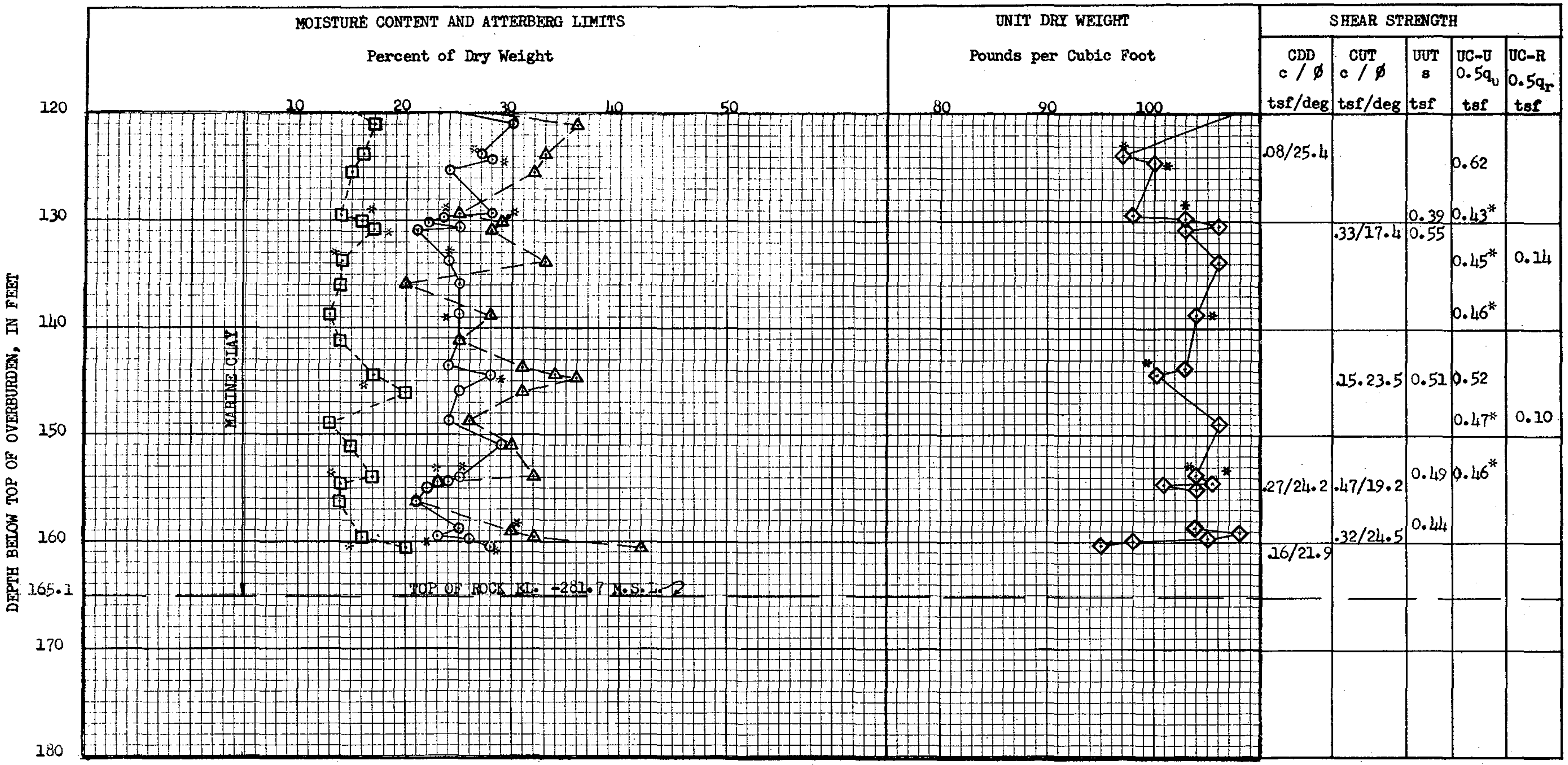
SOILS TEST DATA

BORING 102-D, SHEET 2

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-291

EASTPORT CHANNEL



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
- Top of overburden el. -116.6 M.S.L.
- Soils terminology reference cited on plate 2-35
- Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

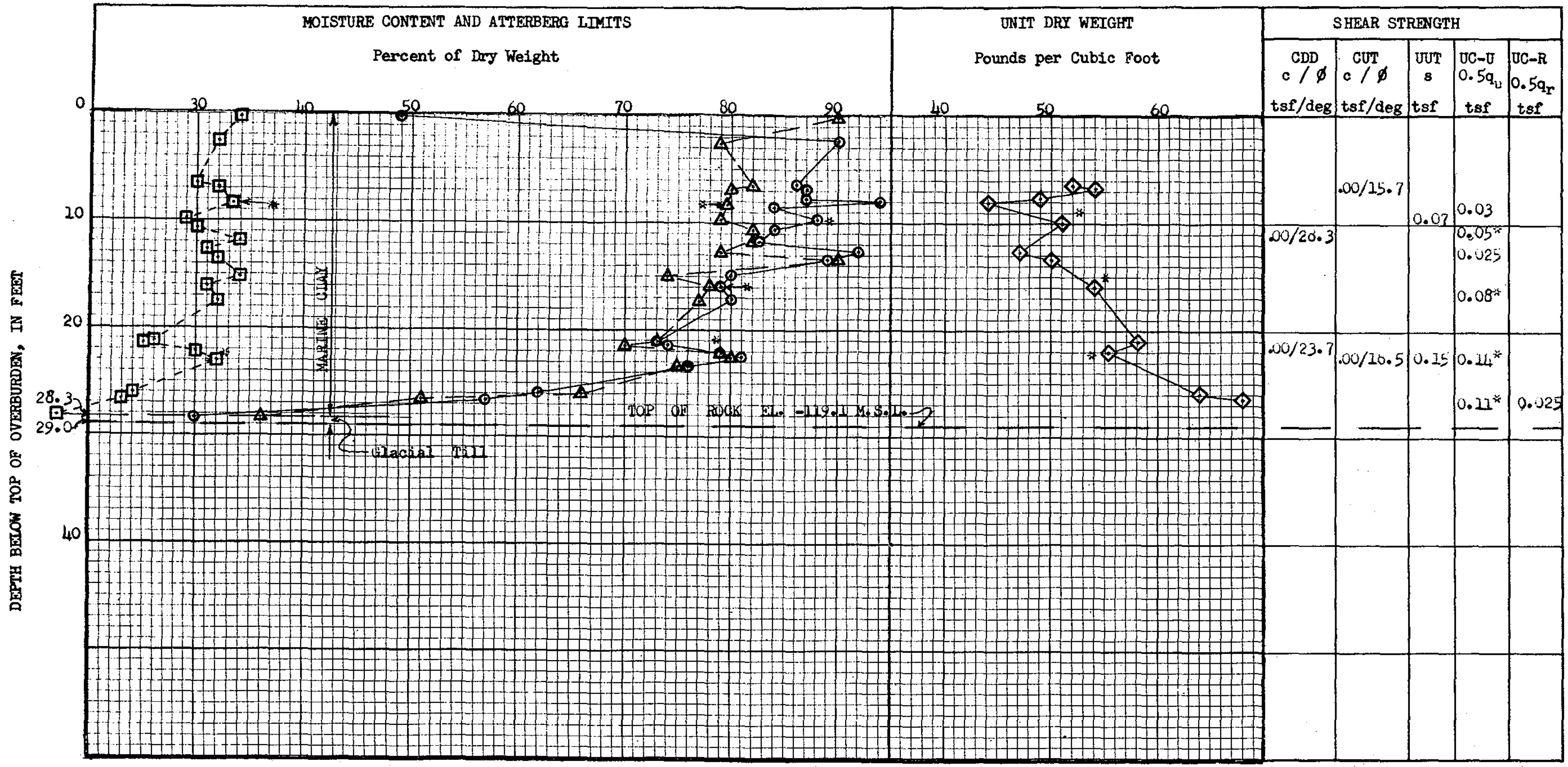
SOILS TEST DATA

BORING 102-D, SHEET 3

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-292

PASSAMAQUODDY BAY



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -90.1 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

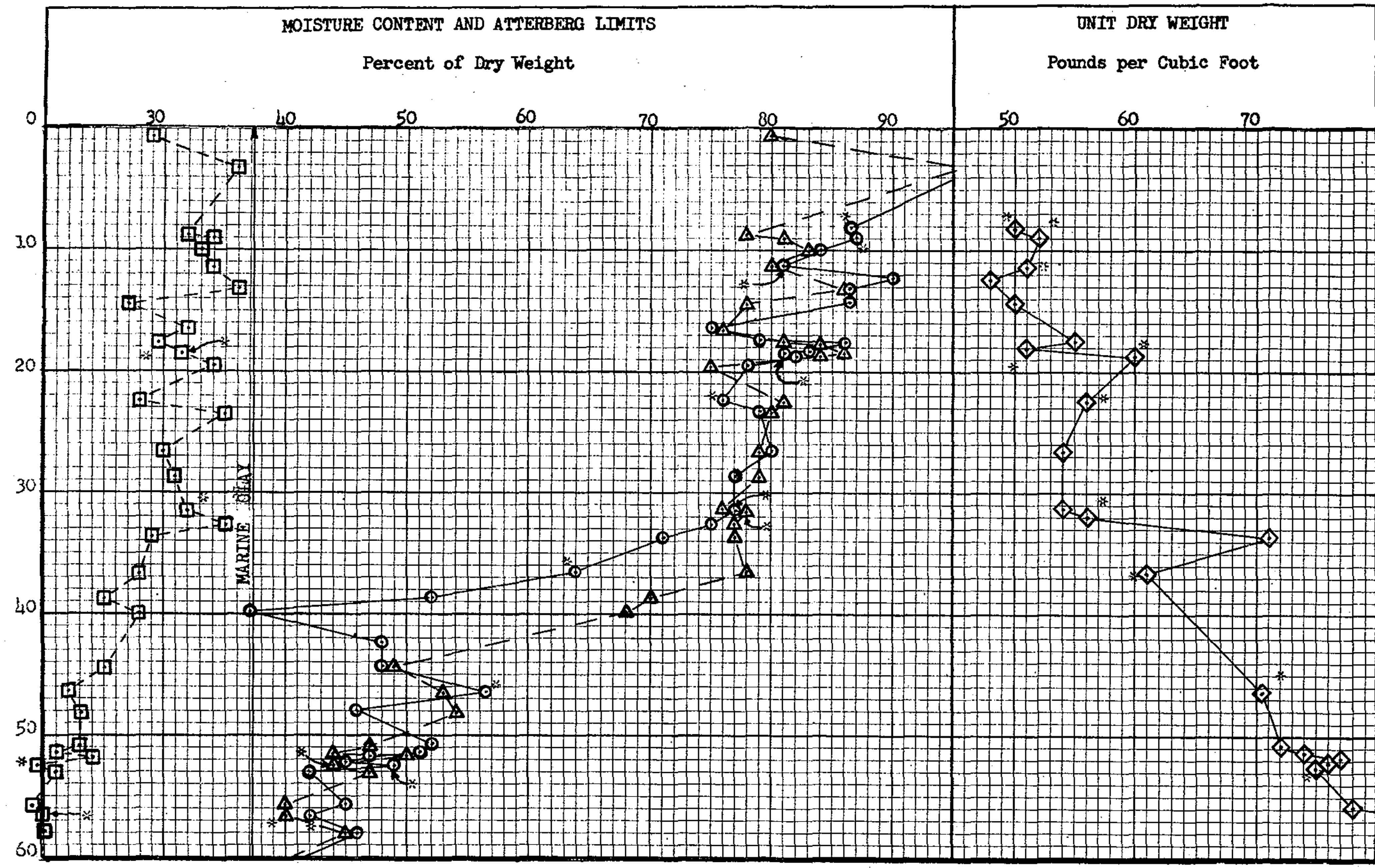
SOILS TEST DATA

BORING 103-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-293

PASSAMAQUODDY BAY



SHEAR STRENGTH

CDD c / Ø tsf/deg	CUT c / Ø tsf/deg	UUT s tsf	UC-U $0.5q_u$ tsf	UC-R $0.5q_r$ tsf
	.00/17.5			
.05/26.5		0.08	0.07	
.04/25.7	.00/19.4	0.12	0.10*	0.010
			0.08*	0.040
.10/23.8	.00/14.7	0.12	0.06	
			0.14*	
			0.15*	0.010
.11/22.4	.11/11.7	0.18	0.13*	
.20/20.1	.00/18.3	0.14	0.14	0.015

LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -106.6 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

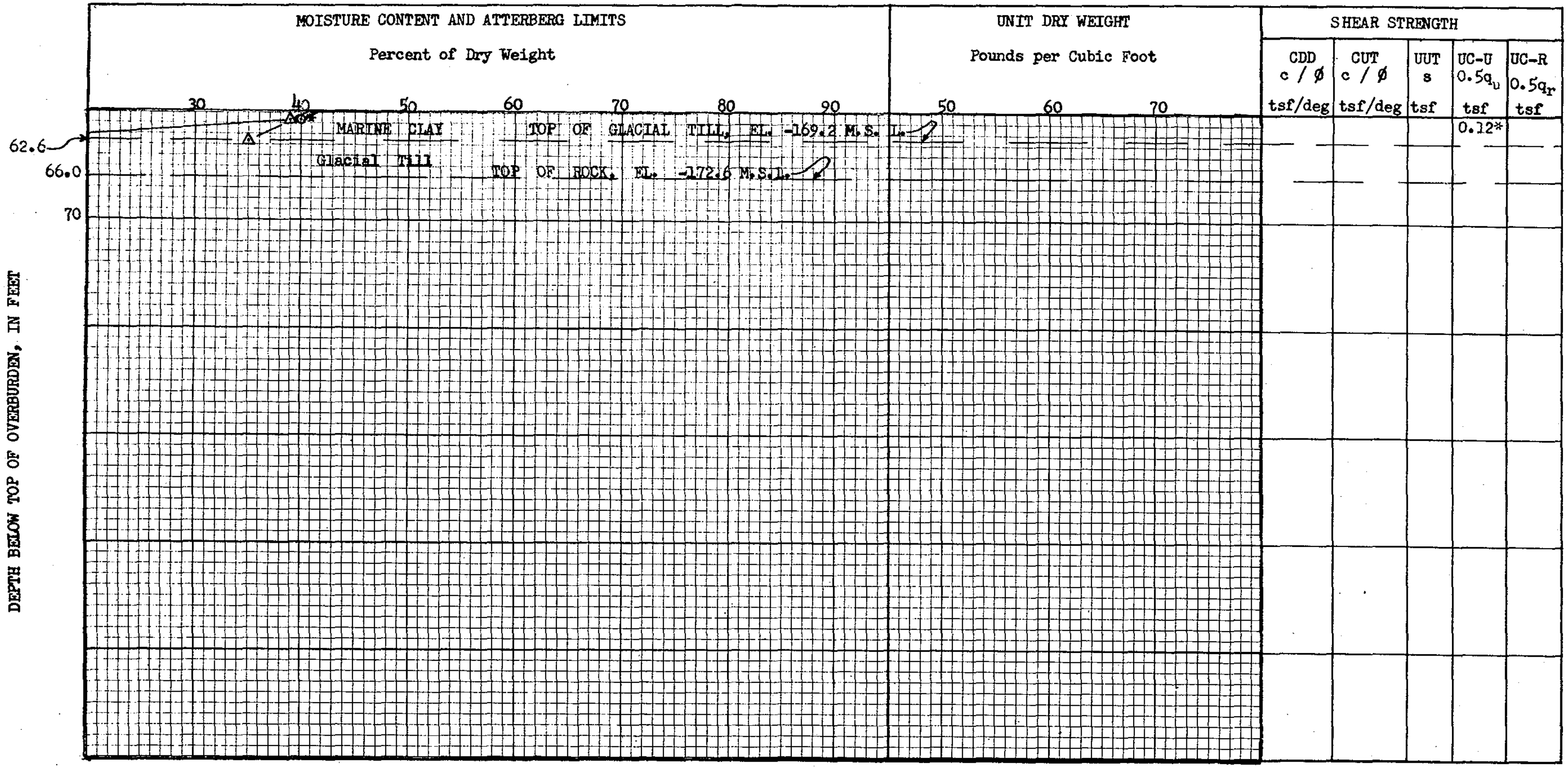
SOILS TEST DATA

BORING 104-D, SHEET 1

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-294

PASSAMAQUODDY BAY



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -106.6 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

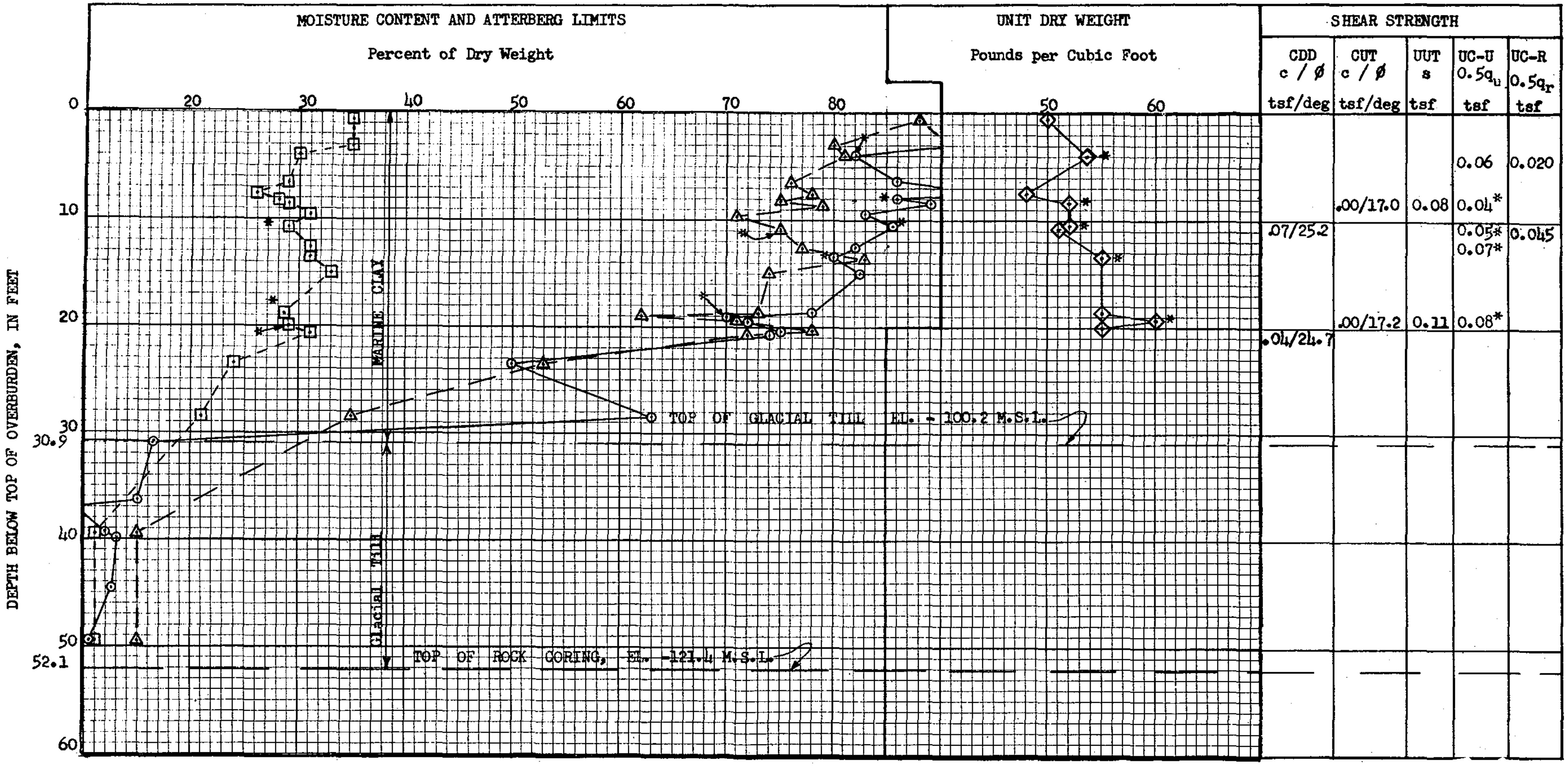
SOILS TEST DATA

BORING 104-D, SHEET 2

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-295

PASSAMAQUODDY BAY



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -69.3 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

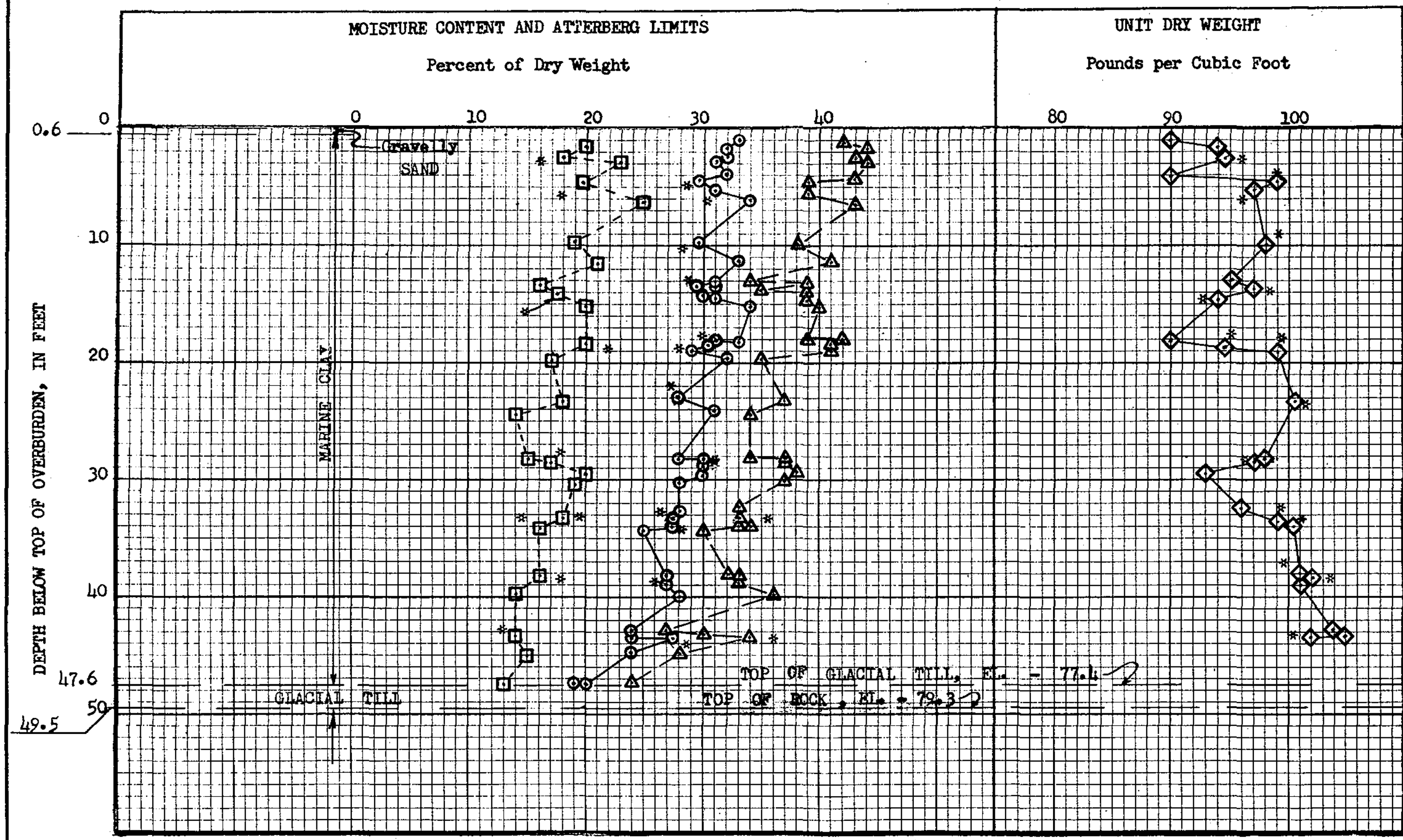
SOILS TEST DATA

BORING 105-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-296

QUODDY ROADS



SHEAR STRENGTH

CDD c / ø tsf/deg	CUT c / ø tsf/deg	UUT s tsf	UC-U $0.5q_u$ tsf	UC-R $0.5q_r$ tsf
.10/22.9	.34/20.5	0.49	0.54	
			0.76*	
			0.52*	0.20
			0.44*	
.08/24.2	.00/24.1	0.46	0.48*	
	.20/17.8	0.39	0.49*	0.18
			0.57*	
.08/25.0	.40/16.5	0.40	0.13	
.16/22.7			0.51*	
		0.50	0.76	
		0.63	0.65*	0.24
	.27/20.0	0.53	0.52	

LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -29.8 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

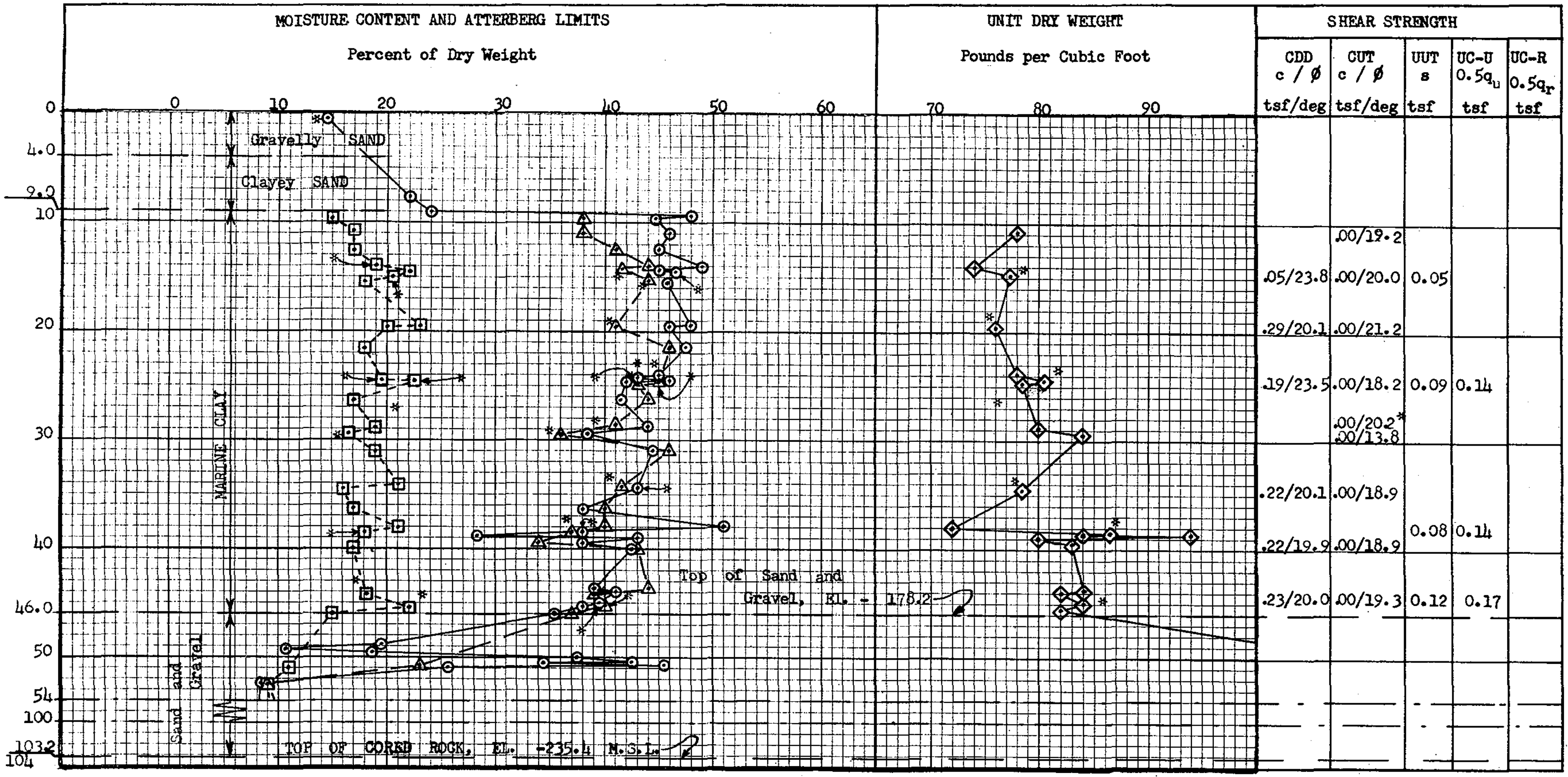
SOILS TEST DATA

BORING 107-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TC7-297

INDIAN RIVER



International Joint Commission
Passamaquoddy Tidal Power Survey

LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -132.2 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

TIDAL PROJECT

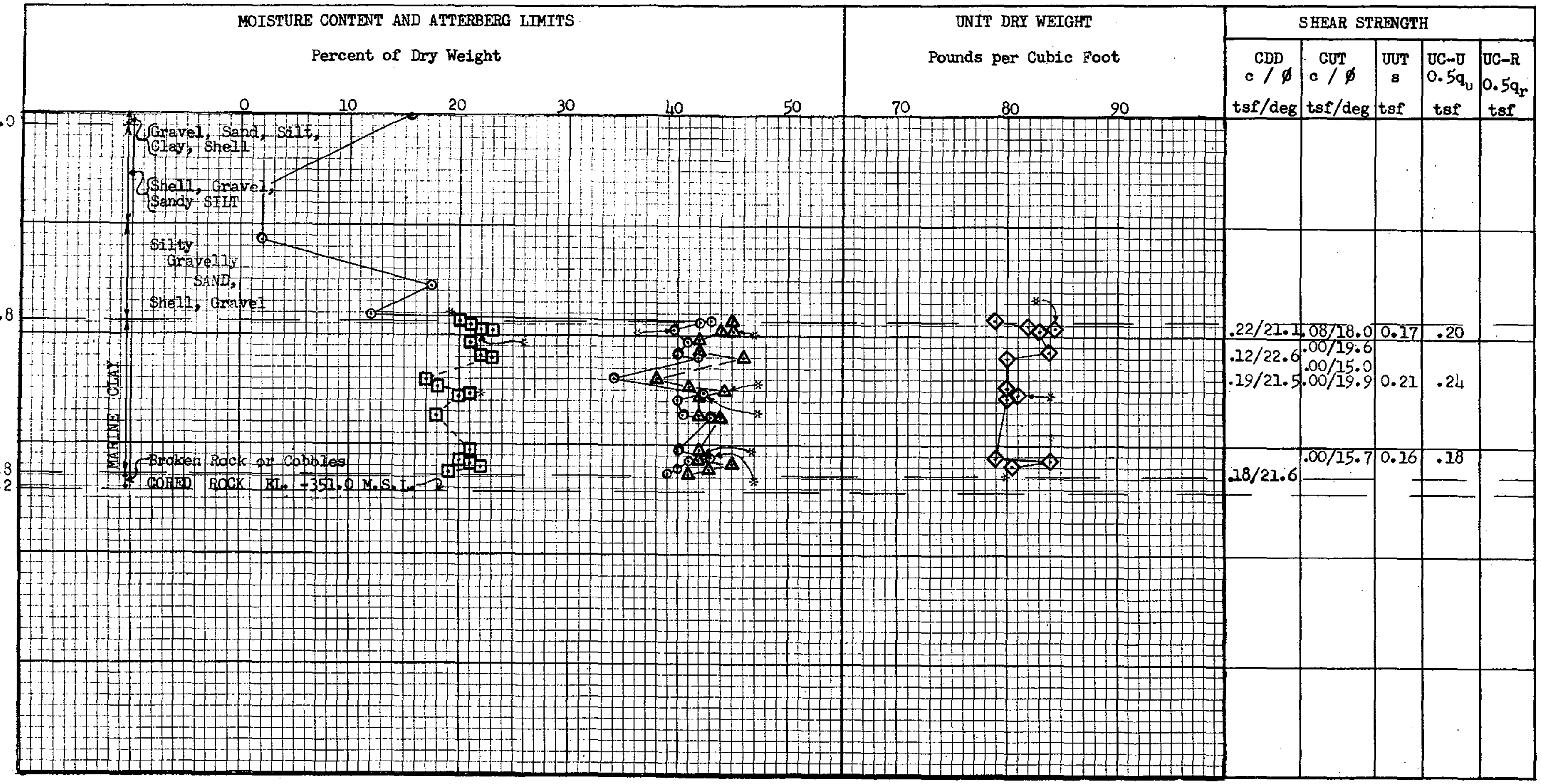
SOILS TEST DATA

BORING 110-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-298

HEAD HARBOUR PASSAGE



International Joint Commission
Passamaquoddy Tidal Power Survey

LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. 316.8
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

TIDAL PROJECT

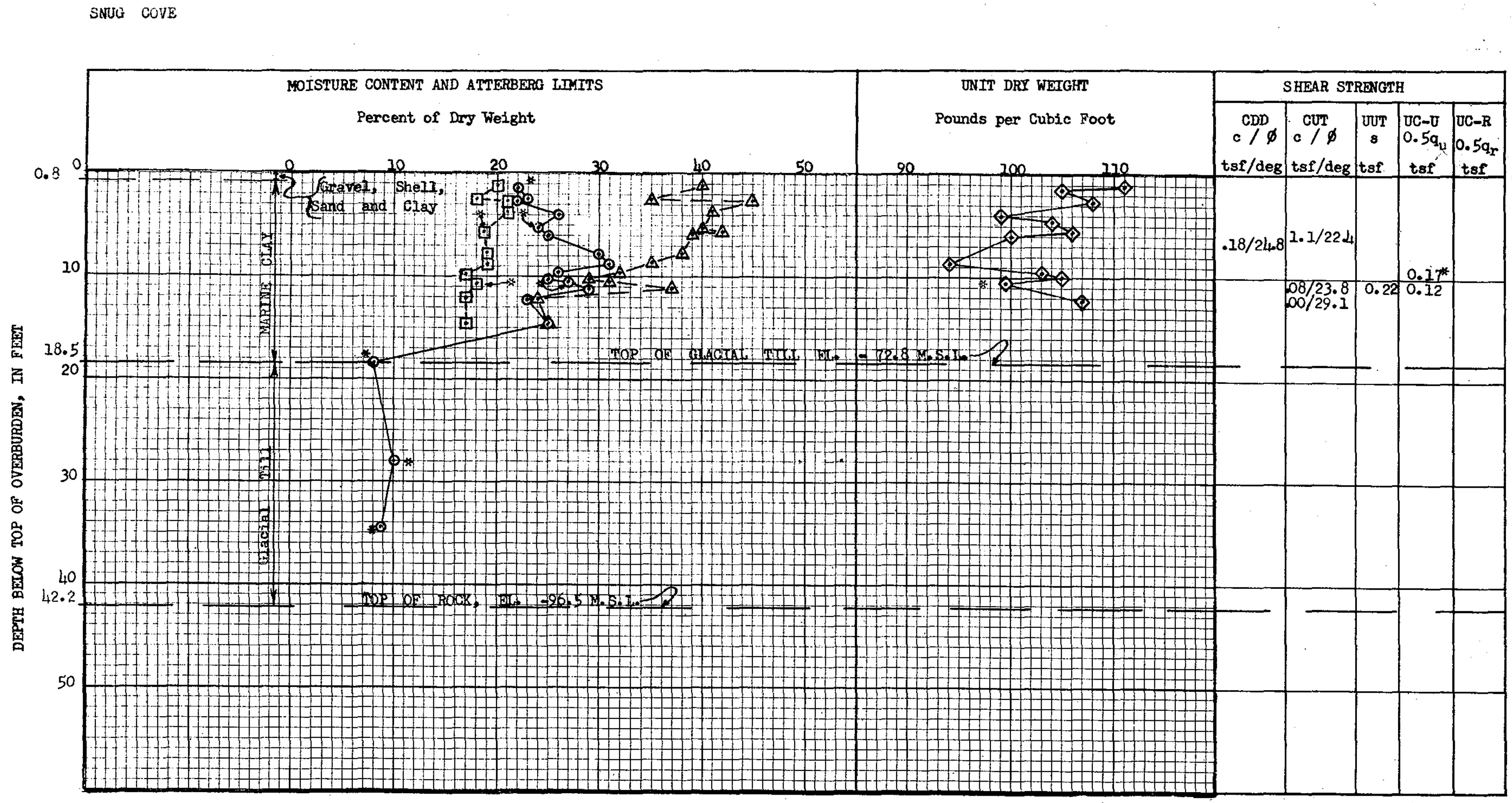
SOILS TEST DATA

BORING 114-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-299

PLATE 2-28



LEGEND
- ⊡ Plastic Limit
- ⊙ Moisture Content
- △ Liquid Limit
- ◇ Unit Dry Weight

TEST DESIGNATIONS
- CDD Consolidated-drained direct shear test
- CUT Consolidated-undrained triaxial compression test
- UUT Unconsolidated-undrained triaxial compression test
- UC-U Unconfined compression test - undisturbed soil
- UC-R Unconfined compression test - remolded soil

NOTES
Top of overburden el. -54.3 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

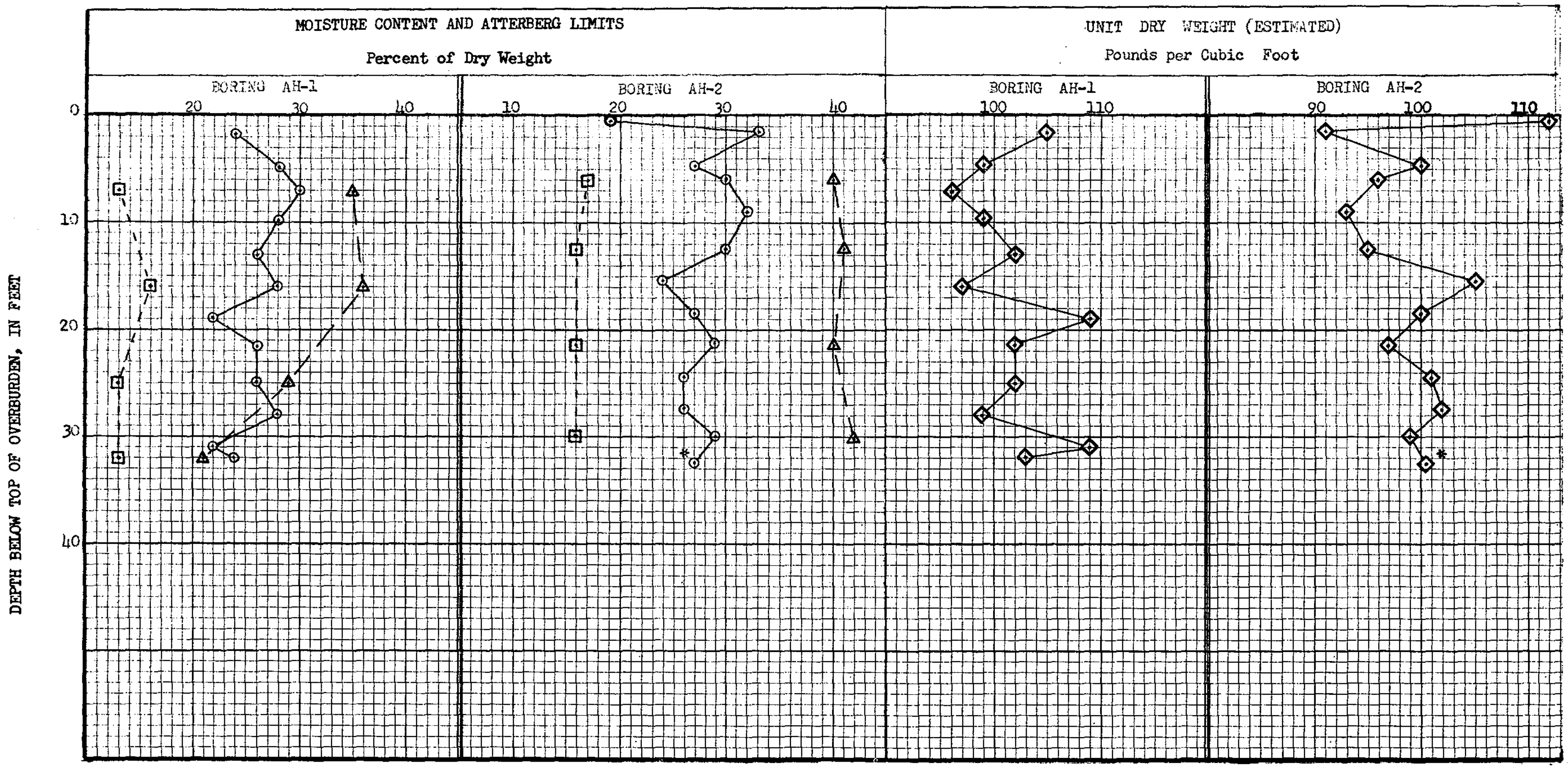
SOILS TEST DATA

BORING 115-D

International Passamaquoddy Engineering Board

October 1959 Dwg No TC7-300

CARRYINGPLACE COVE



LEGEND
⊡ Plastic Limit
⊙ Moisture Content
△ Liquid Limit
◇ Unit Dry Weight

NOTES
Top of overburden el. 0 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

TIDAL PROJECT

SOILS TEST DATA

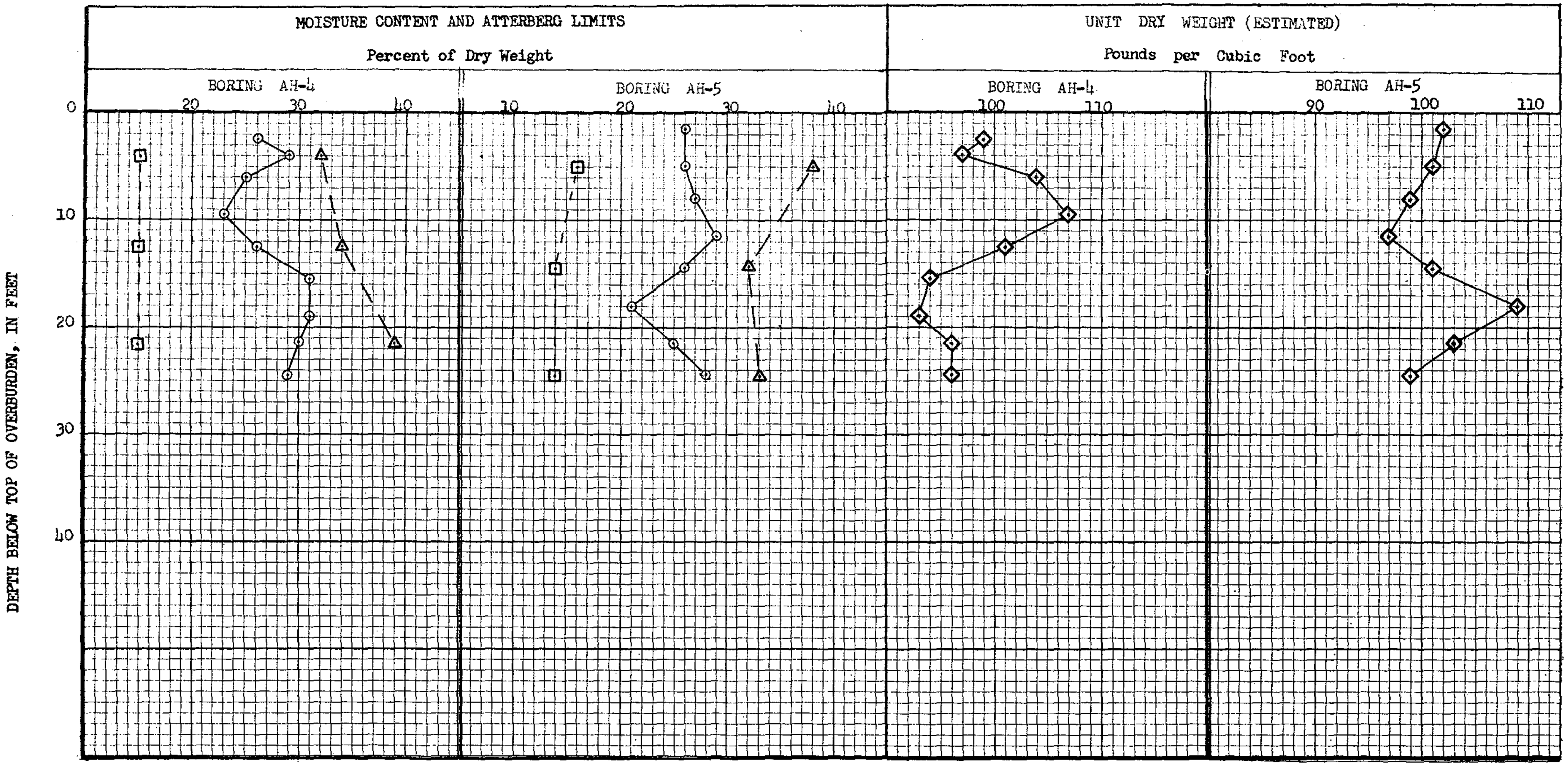
BORINGS AH-1 and AH-2

International Passamaquoddy Engineering Board

October 1959 Dwg No TG7-301

PLATE 2-30

CARRYINGPLACE COVE



LEGEND
- ⊡ **Plastic Limit**
- ⊙ **Moisture Content**
- △ **Liquid Limit**
- ◇ **Unit Dry Weight**

NOTES
Top of overburden el. -2 M.S.L.
Soils terminology reference cited on plate 2-35
Asterisks indicate average value of two or more tests

International Joint Commission
Passamaquoddy Tidal Power Survey

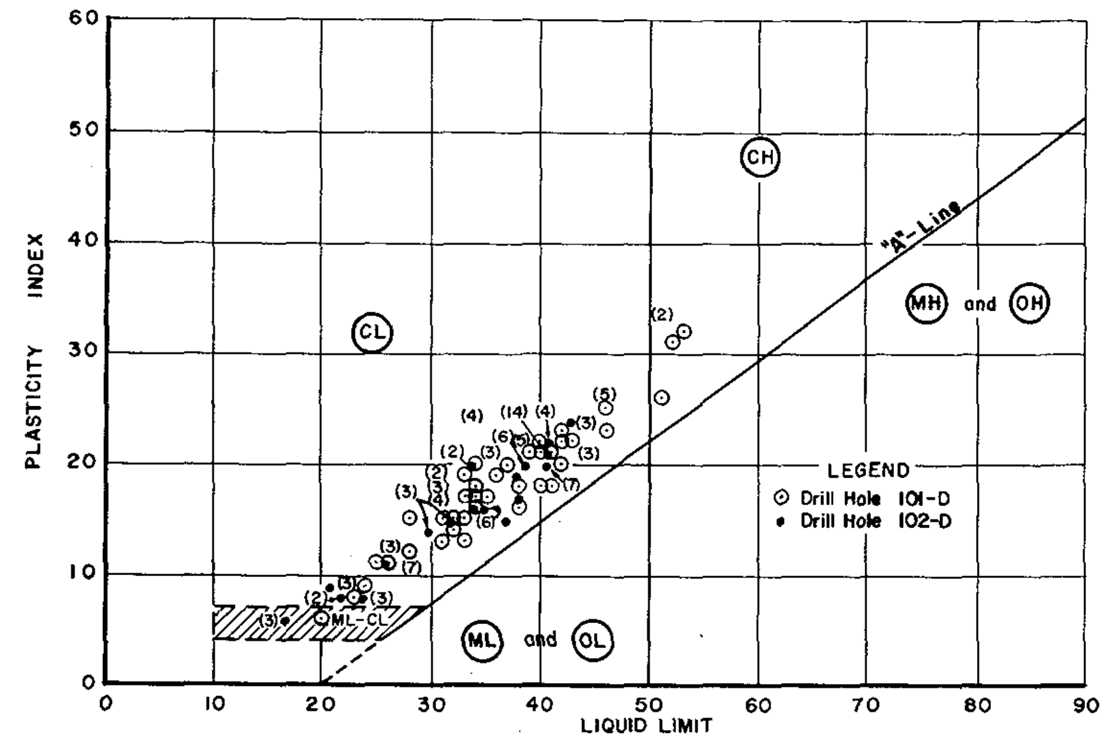
TIDAL PROJECT

SOILS TEST DATA

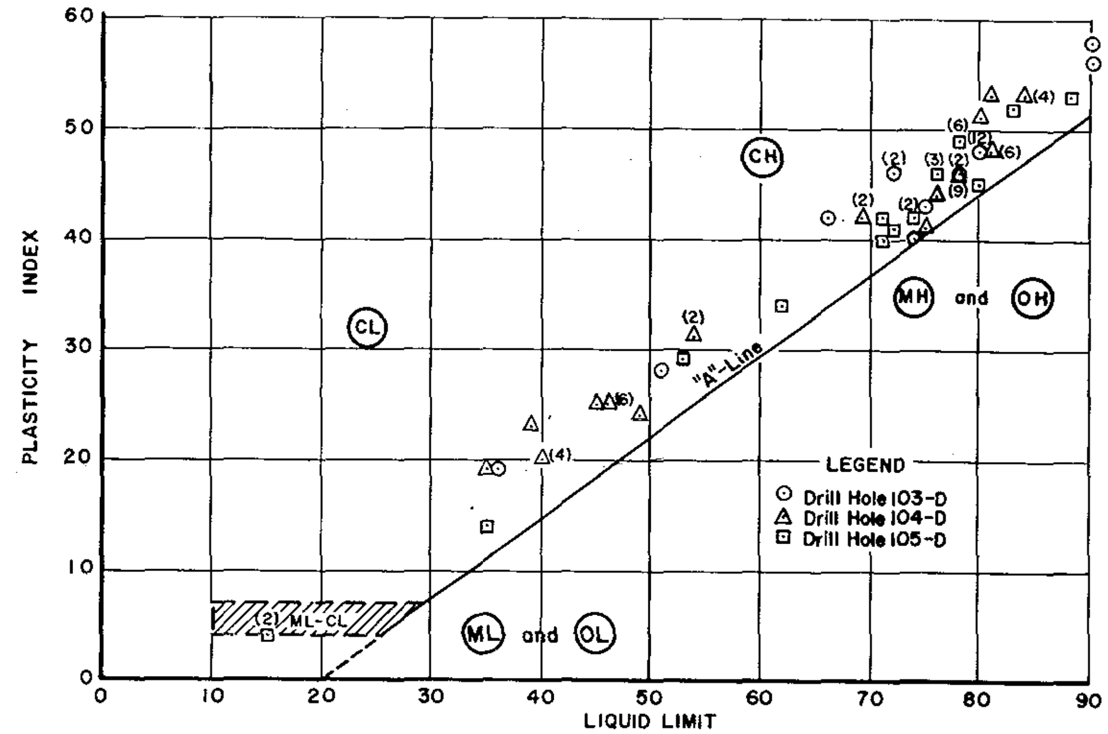
BORINGS AH-4 and AH-5

International Passamaquoddy Engineering Board

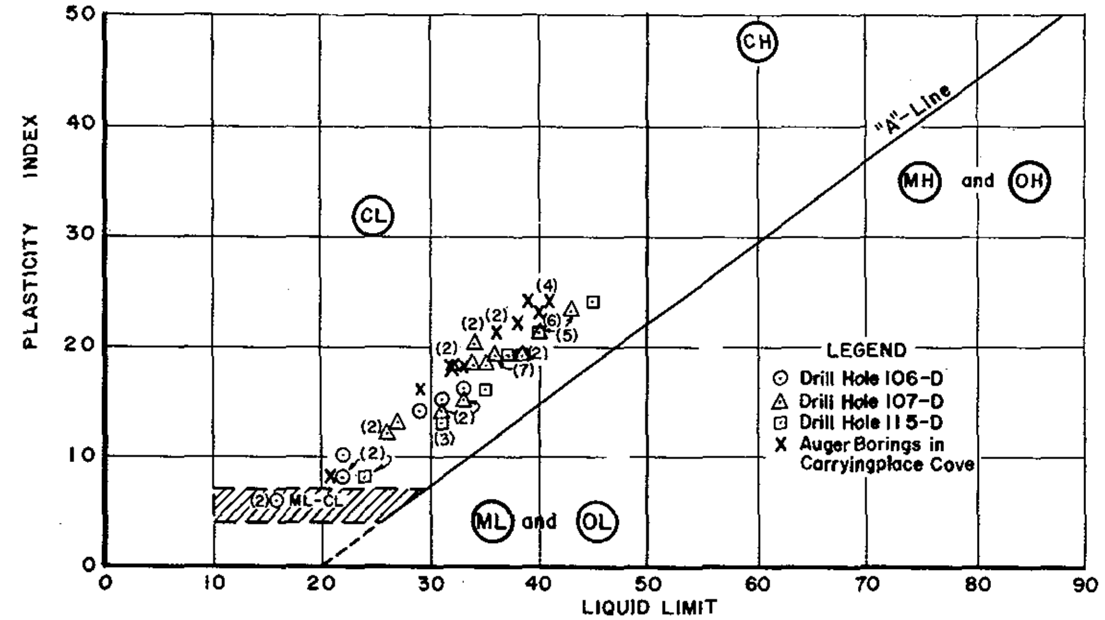
October 1959 Dwg No TG7-302



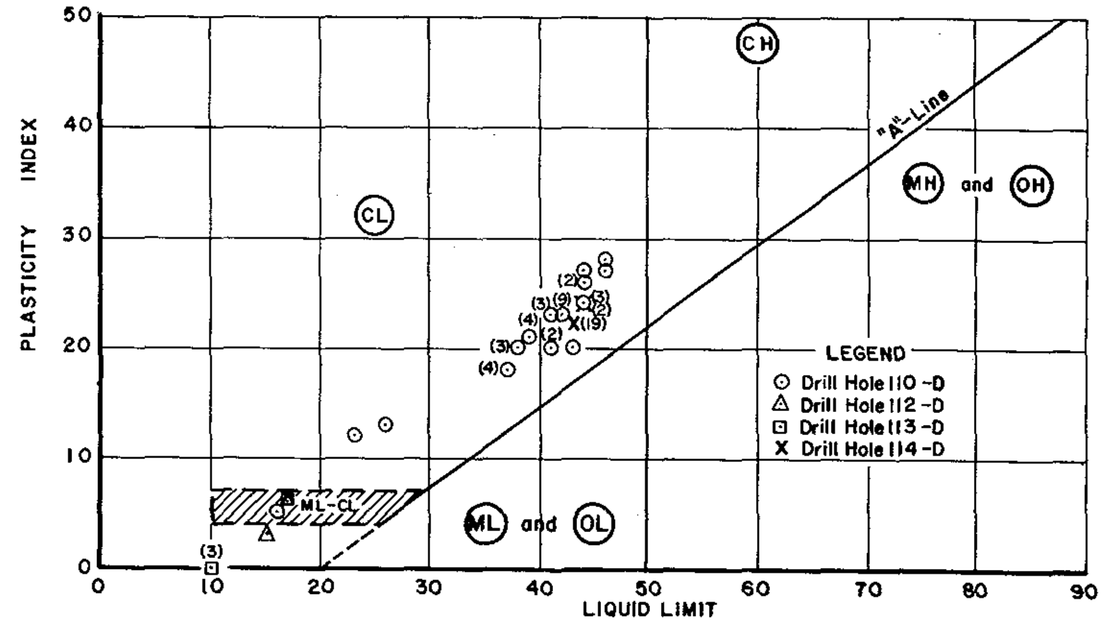
DRILL HOLE 101-D, 102-D



DRILL HOLE 103-D, 104-D, 105-D



DRILL HOLE 106-D, 107-D, 115-D
AND AUGER BORINGS IN CARRYINGPLACE COVE



DRILL HOLE 110-D, 112-D, 113-D, AND 114-D

SOIL CLASSIFICATION

CH - Inorganic clay of high plasticity
CL - Inorganic clay of low to medium plasticity
MH - Inorganic silt of high plasticity
ML - Inorganic silt of low to medium plasticity
OH - Organic clay of high plasticity
OL - Organic silt and clay of low plasticity

NOTES

1. Soils types are designated in accordance with the Unified Soils Classification of the U.S. Army Corps of Engineers.
2. Drill hole locations are shown on plate 2-2.
3. Figures in ( ) indicate number of tests represented by plotted point.

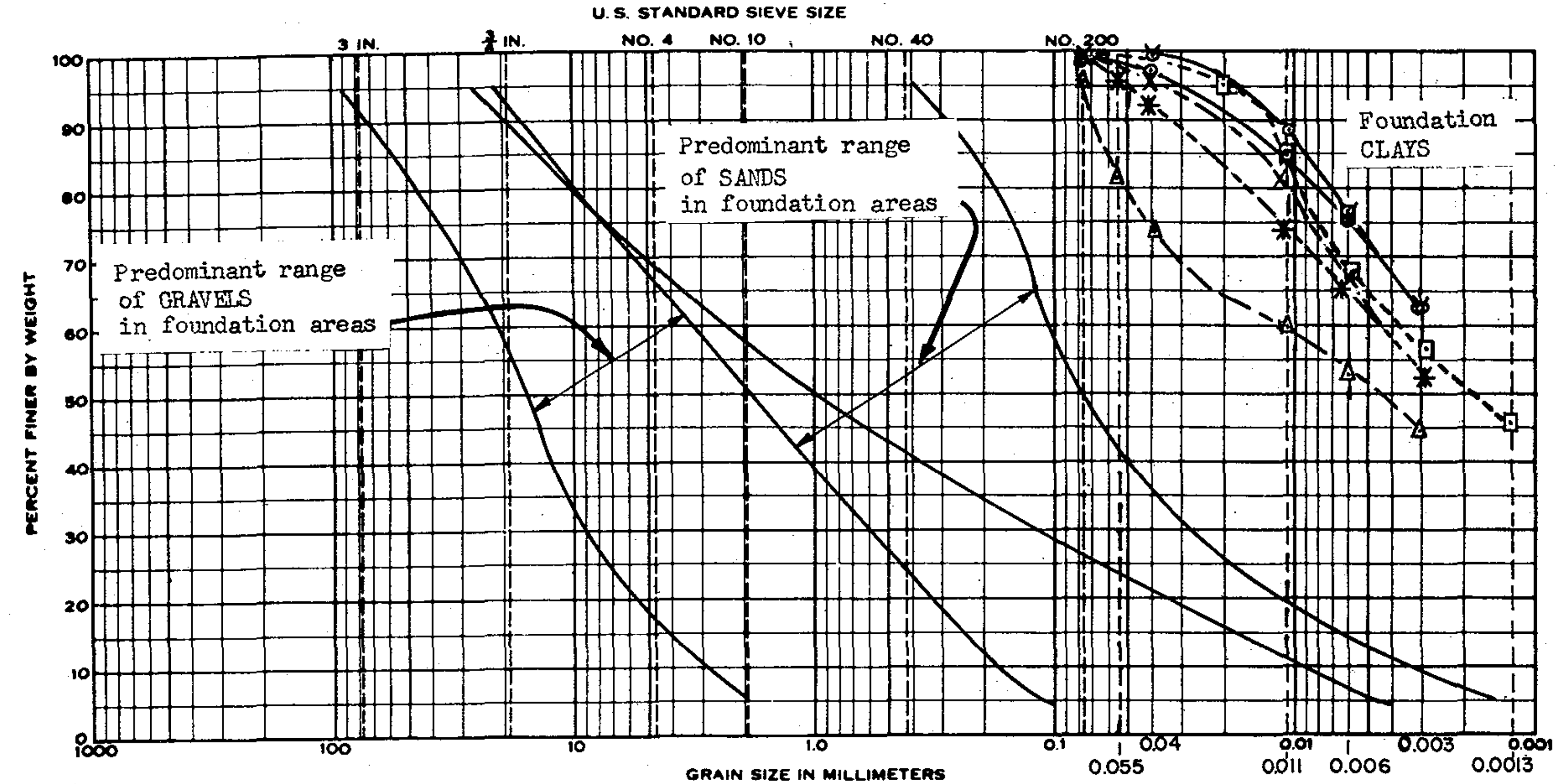
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

SOIL PLASTICITY CHARTS

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-303



International Joint Commission
Passamaquoddy Tidal Power Survey

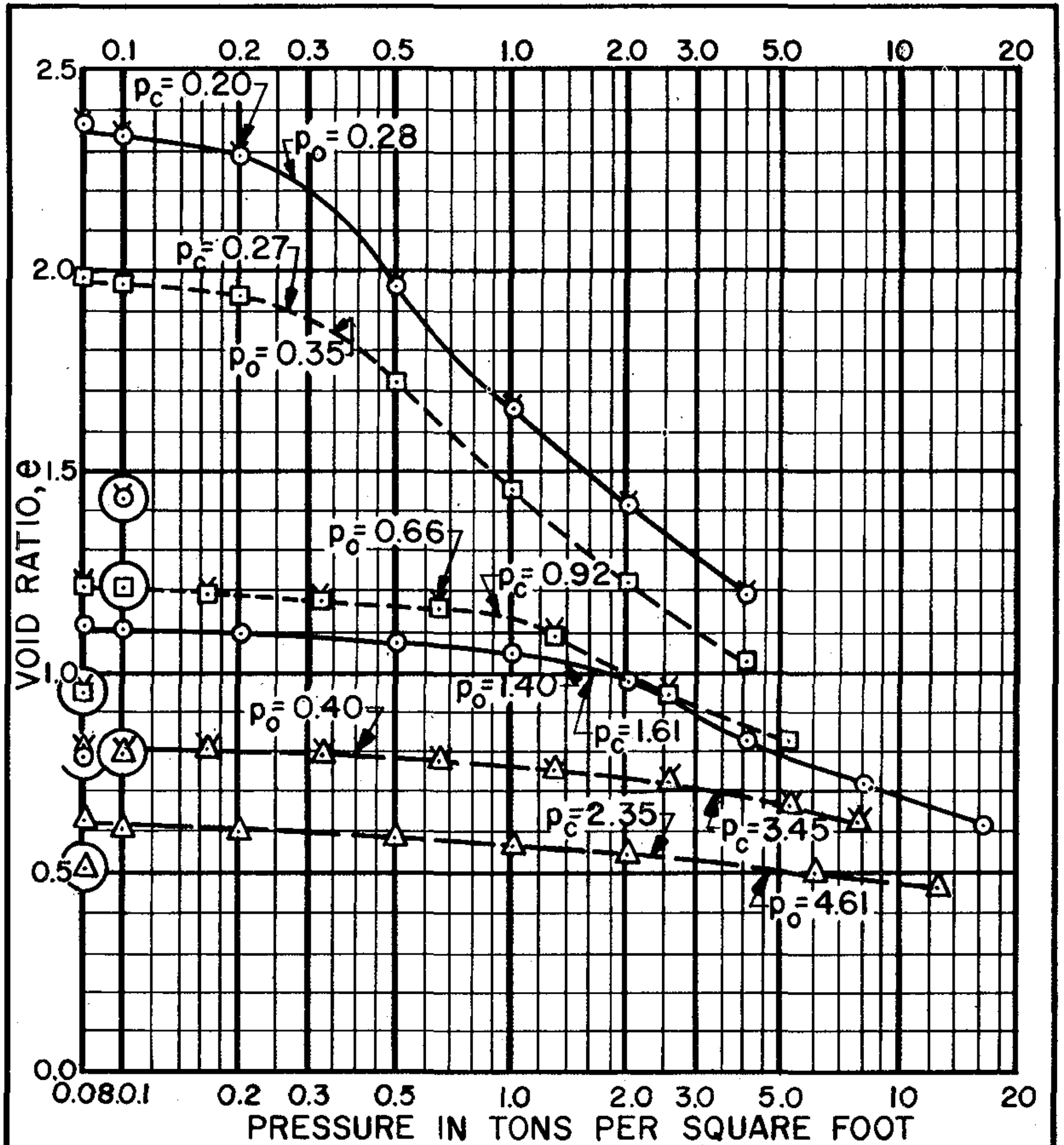
Hole No.	Sample No.	Elev.	Depth	Class	NatWC	LL	PL	PI	Legend
101-D	14	-108.5	50.0	CL	40	42	23	19	⊙———
102-D	34	-270.4	153.8	CL	26	32	17	15	△— — —
103-D	6	-112.1	22.0	CL	78	79	30	49	⊡-----
104-D	5	-125.5	18.9	CL	82	84	31	53	X — — —
107-D	4	- 43.3	13.5	CL	31	39	18	21	✱----
114-DA	3	-335.8	19.0	CL	42	45	21	24	♉———

TIDAL PROJECT
GRADATION CURVES
OF TYPICAL FOUNDATION SOILS

International Passamaquoddy Engineering Board

October 1959

Dwg No TG7-129



LEGEND	HOLE No.	SPLE. No.
⊙	101 – D	14
△	102 – D	34
⊡	103 – D	6
⊙̆	104 – D	5
△̆	107 – D	4
⊡̆	114 – DA	3

For sample depth and identification, see plate 2-35.

Encircled symbols indicate final rebound points.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

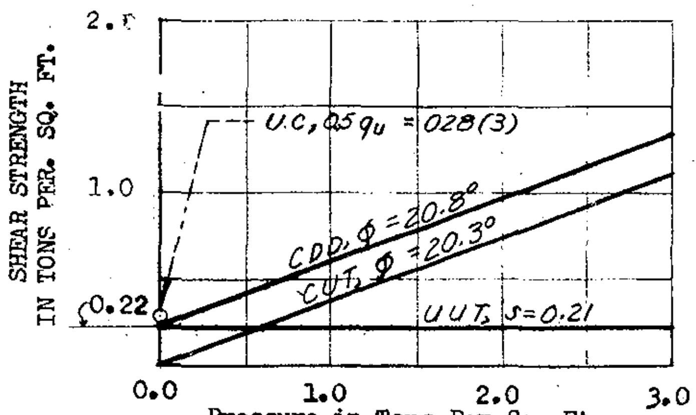
TIDAL PROJECT

TYPICAL CONSOLIDATION DATA

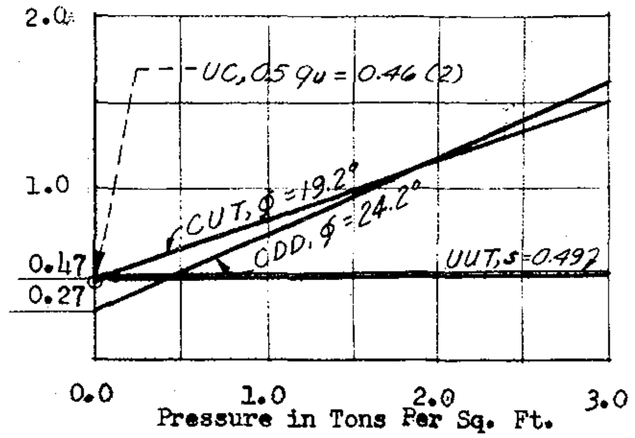
PRESSURE – VOID RATIO CURVES

International Passamaquoddy Engineering Board

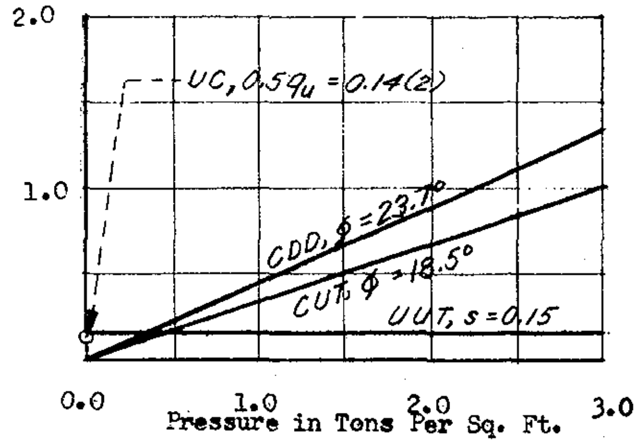
OCTOBER 1959 Dwg. No. TG7-130



JOHNSON BAY
HOLE 101-D, SAMPLE 14



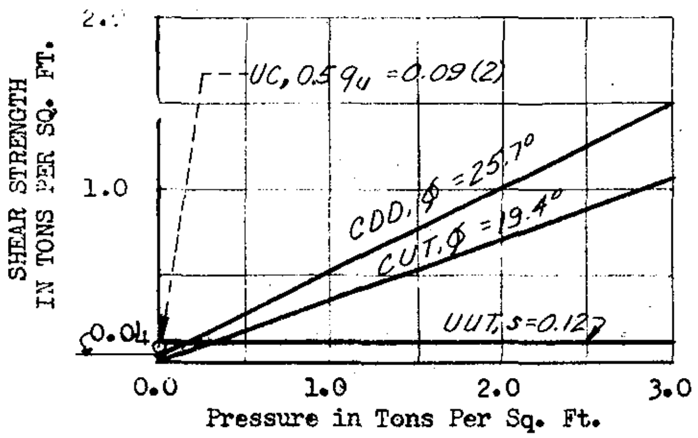
EASTPORT CHANNEL
HOLE 102-D, Sample 34



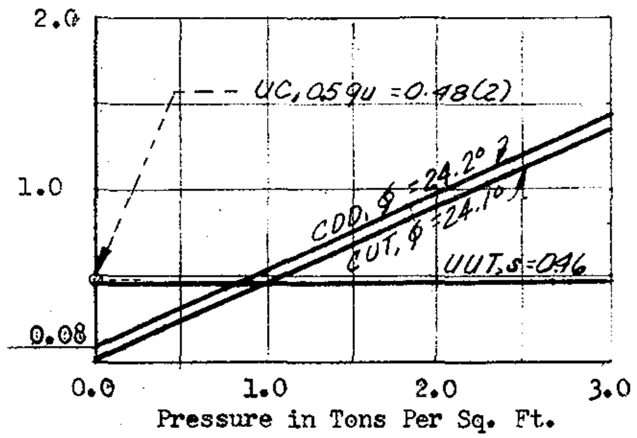
PASSAMAQUODDY BAY
HOLF 103-D, Sample 6

Test Designations:

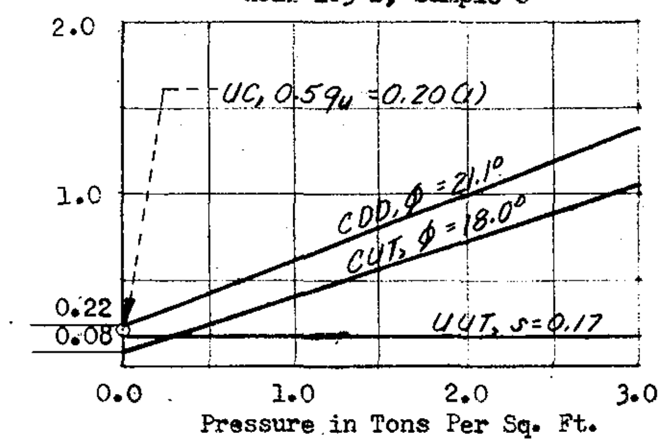
- CDD = Consolidated-drained direct shear test
- CUT = Consolidated-undrained triaxial compression test
- UUT = Unconsolidated-undrained triaxial compression test
- UC = Unconfined compression test



PASSAMAQUODDY BAY
HOLE 104-D, SAMPLE 5



QUODDY ROADS
HOLE 107-D, SAMPLE 4



HEAD HARBOUR PASSAGE
HOLE 114-DA, SAMPLE 3

Hole No.	Sple No.	Depth to Top	Elev. of Top	Gradation % Gr	% Sa	% Fi	Atterberg Limits LL	PL	PI	USC	G	w_i	γ_{di}	e_i	Consolidation Pressure - Void Ratio Data $e_{0.5}$	$e_{1.0}$	$e_{2.0}$	$e_{3.0}$	$e_{5.0}$	$e_{10.0}$	e_r	p_c	p_o
101-D	14	50.3	-108.9	0	0	100	43	20	23	CL	2.77	38	86	1.116	1.075	1.051	0.981	0.900	0.798	0.692	0.786	1.61	1.40
102-D	34	154.1	-270.7	0	2	98	27	15	12	CL	2.76	24	104	0.623	0.588	0.565	0.545	0.530	0.508	0.477	0.510	2.35	4.61
103-D	6	21.8	-111.9	0	0	100	76	29	47	CH	2.74	77	56	1.981	1.720	1.452	1.222	1.108	0.972		1.210	0.27	0.35
104-D	5	18.2	-124.8	0	0	100	84	31	53	CH	2.71	82	55	2.366	1.959	1.656	1.413	1.285	1.132		1.433	0.22	0.28
107-D	4	13.9	- 43.7	0	2	98	37	17	20	CL	2.78	31	95	0.810	0.782	0.762	0.734	0.708	0.668	0.588	0.797	3.45	0.40
114-DA	3	19.3	-336.1	0	0	100	45	22	23	CL	2.79	41	83	1.214	1.171	1.111	1.000	0.921	0.832	0.701	0.950	0.92	0.66

NOTES:

(1) Terminology in table headings is in accordance with "Glossary of Terms and Definitions in Soil Mechanics" shown on pages 1826-1 through 1826-40 of the October 1958 Journal of the Soil Mechanics and Foundation Division of the Proceedings of the American Society of Civil Engineers, except for the term "s" which indicates the shearing strength obtained from an unconsolidated undrained triaxial compression test.

(2) U.S.C. indicates Unified Soil Classification of the Corps of Engineers, U. S. Army.

(3) Figures in parentheses indicate number of tests averaged.

International Joint Commission

Passamaquoddy Tidal Power Survey

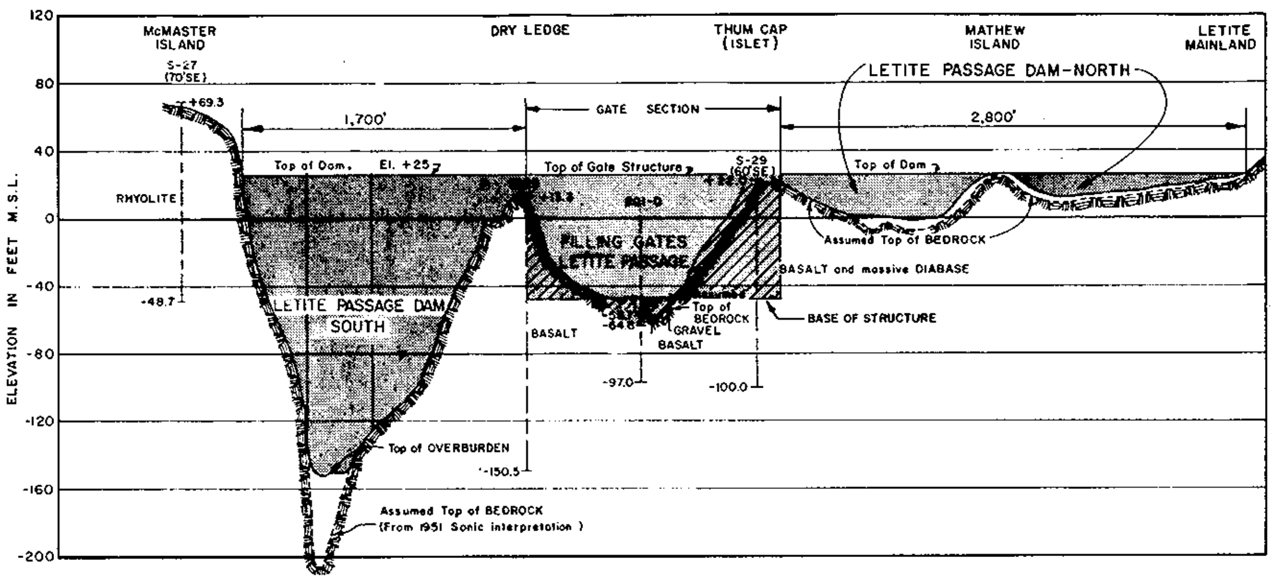
TIDAL PROJECT

SHEAR STRENGTH AND CONSOLIDATION DATA

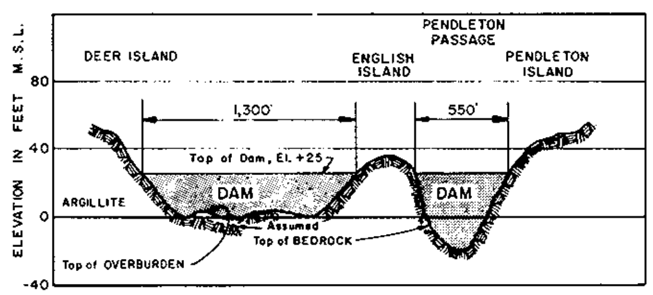
FOR TYPICAL FOUNDATION CLAYS

International Passamaquoddy Engineering Board

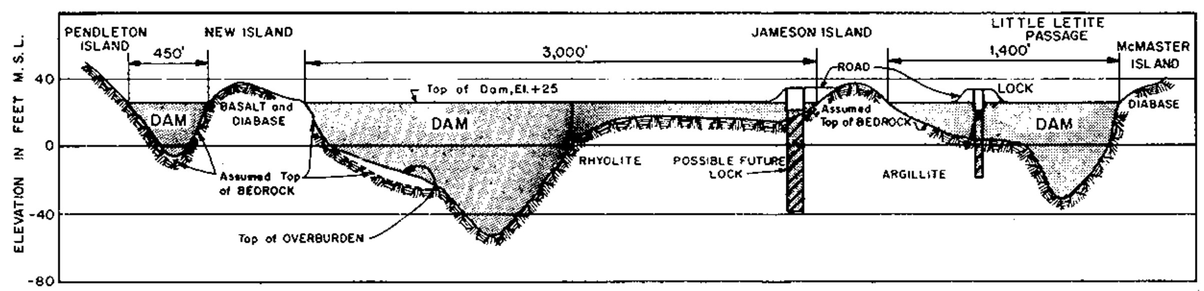
October 1959 Dwg No TG7-131



AREA I - LETITE PASSAGE - PROFILE ALONG ℄ GATES and DAMS

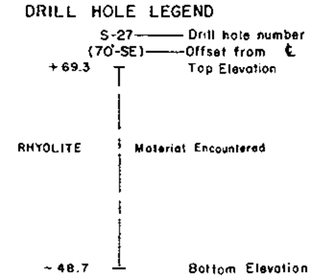


AREA 2-PENDLETON PASSAGE-PROFILE ALONG ℄ DAMS



AREA 2-LITTLE LETITE PASSAGE-PROFILE ALONG ℄ DAMS

DRILL HOLE LEGEND



Notes
All elevations are referred to mean sea level
Plans of areas 1 and 2 are shown in appendix 1, Topography and Underwater Mapping.

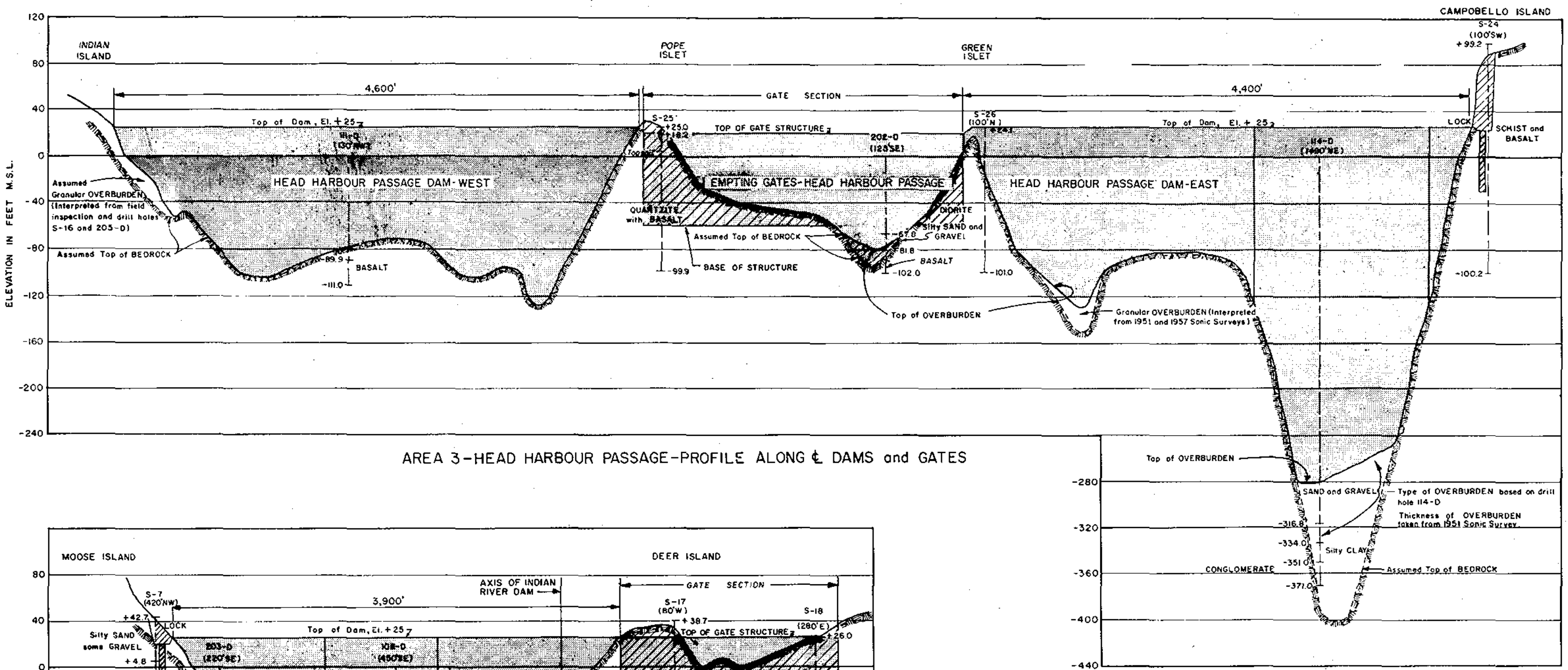
HORIZONTAL SCALE IN FEET
400 0 400 800 1200

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

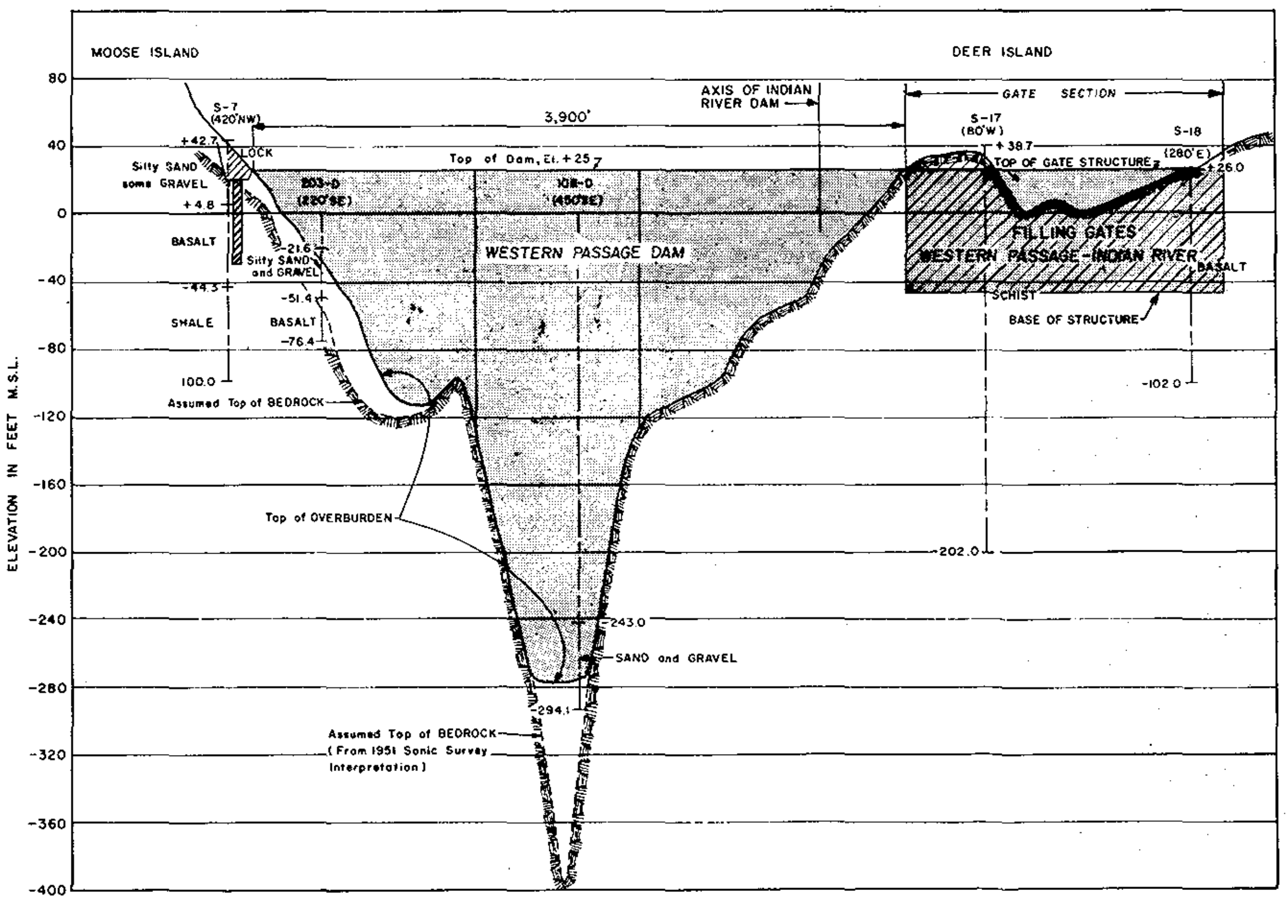
TIDAL PROJECT
GEOLOGIC PROFILES
AREAS I AND 2

International Passamaquoddy Engineering Board

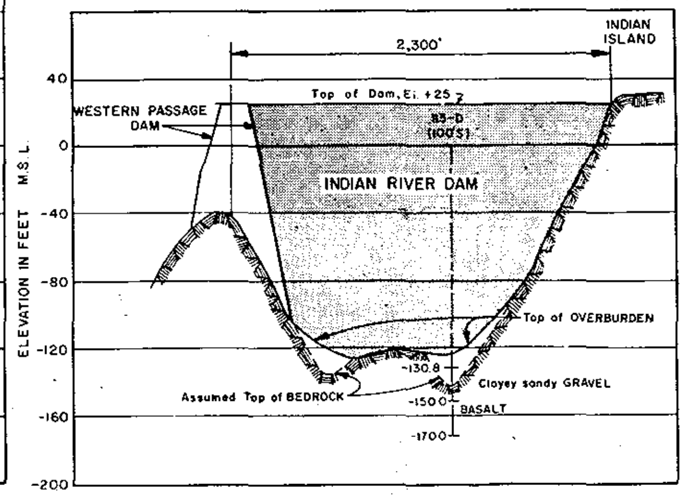
OCTOBER 1959 Dwg. No TG7-132



AREA 3-HEAD HARBOUR PASSAGE-PROFILE ALONG ℄ DAMS and GATES



AREA 4-WESTERN PASSAGE-PROFILE ALONG ℄ DAM



AREA 4-INDIAN RIVER-PROFILE ALONG ℄ DAM

Notes:

All elevations are referred to mean sea level.

Plans of areas 3 and 4 are shown in appendix I, Topography and Underwater Mapping.

Drill hole legend is shown on plate 2-36.

HORIZONTAL SCALE IN FEET
400 0 400 800 1200

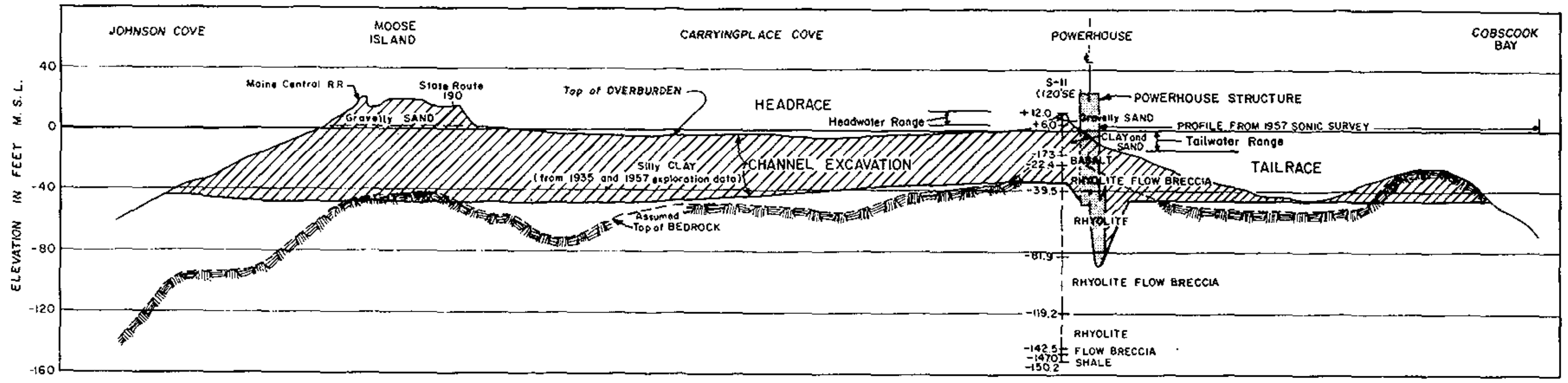
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

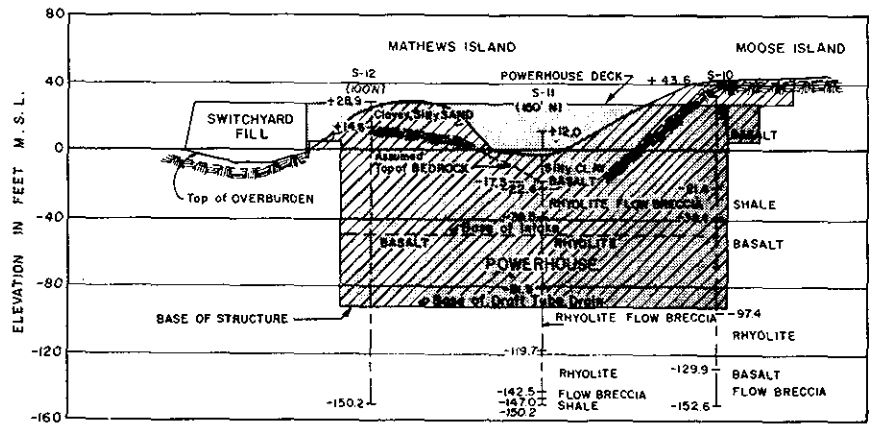
GEOLOGIC PROFILES AREAS 3 AND 4

International Passamaquoddy Engineering Board

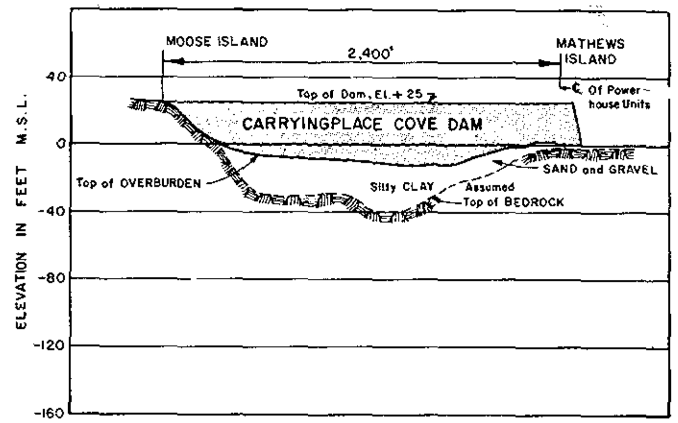
OCTOBER 1959 Dwg. No. TG7-133



AREA 5 - JOHNSON COVE TO CARRYINGPLACE COVE - PROFILE ALONG ℄ HEADRACE AND TAILRACE

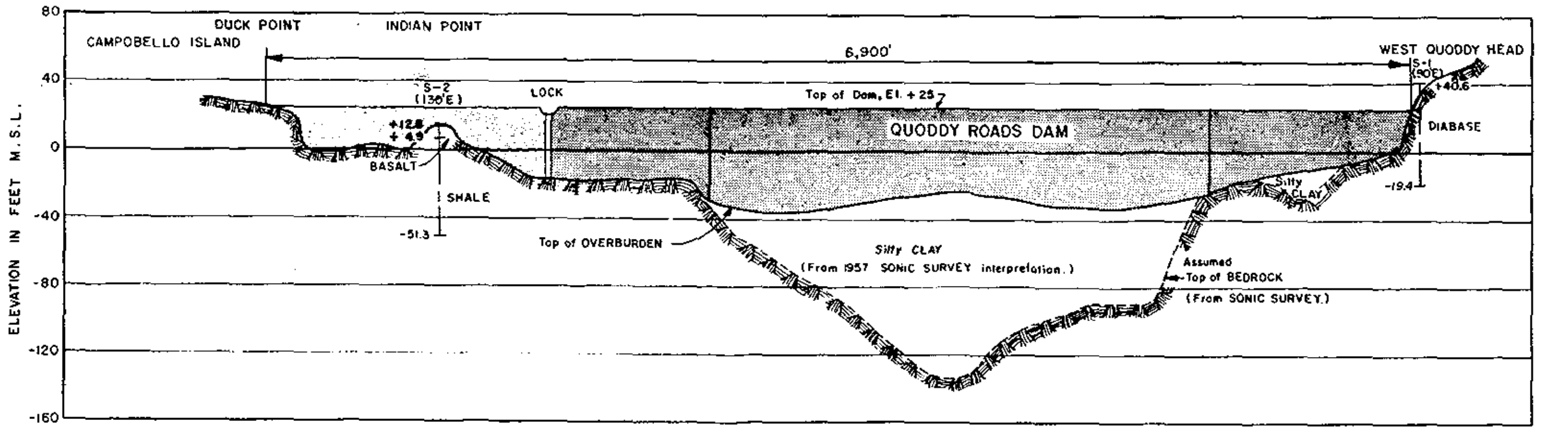


AREA 5 - CARRYINGPLACE COVE - PROFILE ALONG ℄ POWERHOUSE



AREA 5 - CARRYINGPLACE COVE - PROFILE ALONG ℄ DAM

Notes:
All elevations are referred to mean sea level.
Plans of areas 5 and 6 are shown in appendix I, Topography and Underwater Mapping.
Drill hole legend is shown on plate 2-36.



AREA 6 - QUODDY ROADS - PROFILE ALONG ℄ DAM

HORIZONTAL SCALE IN FEET
400 0 400 800 1200

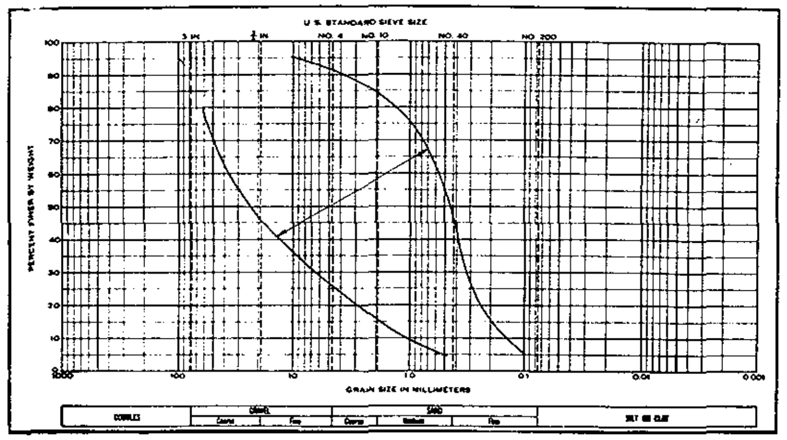
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

GEOLOGIC PROFILES
AREAS 5 AND 6

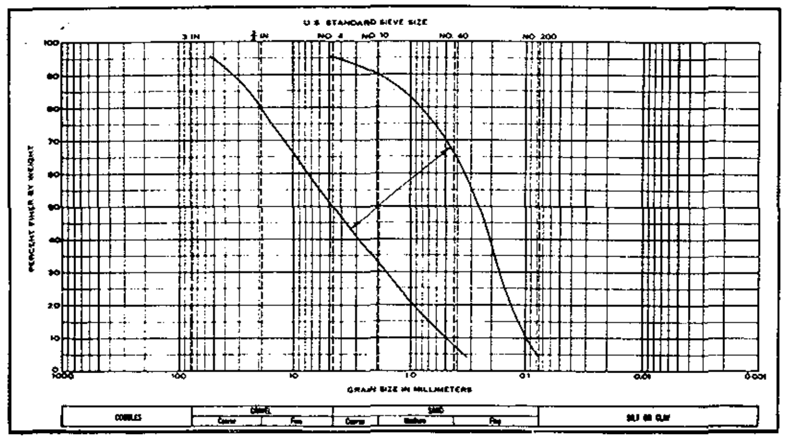
International Passamaquoddy Engineering Board

OCTOBER 1959
Dwg. No. TG7-134



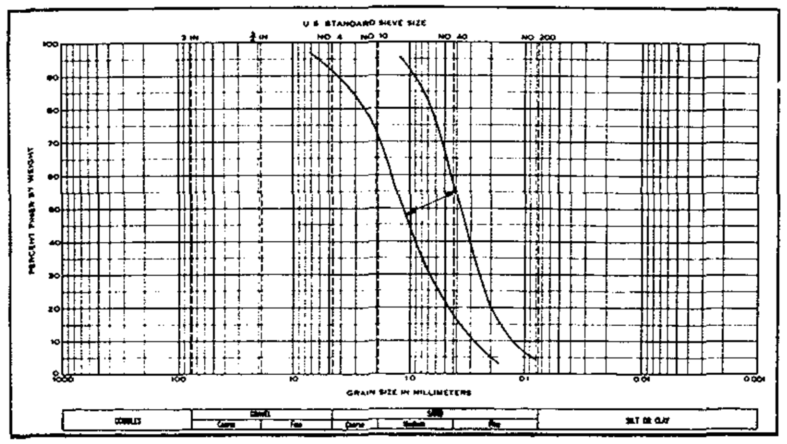
BETHEL TERRACE

GRADATION RANGE OF MATERIAL



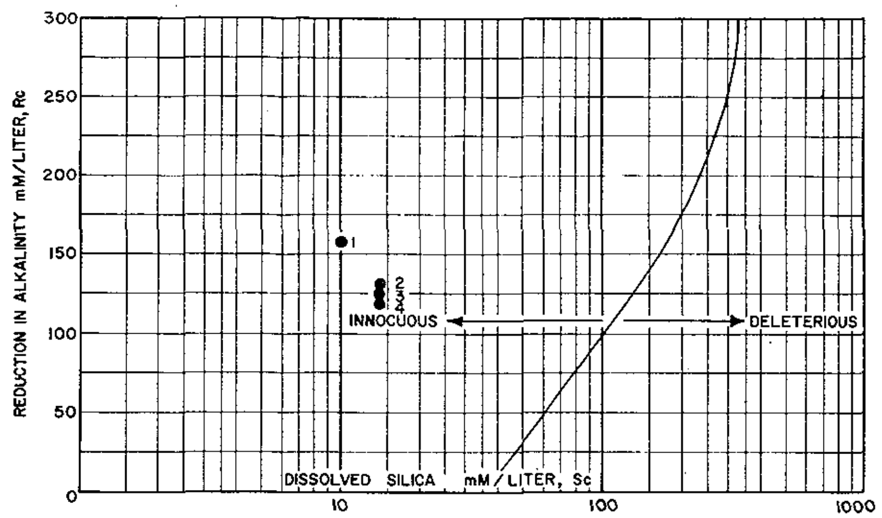
DENNYSVILLE

GRADATION RANGE OF MATERIAL



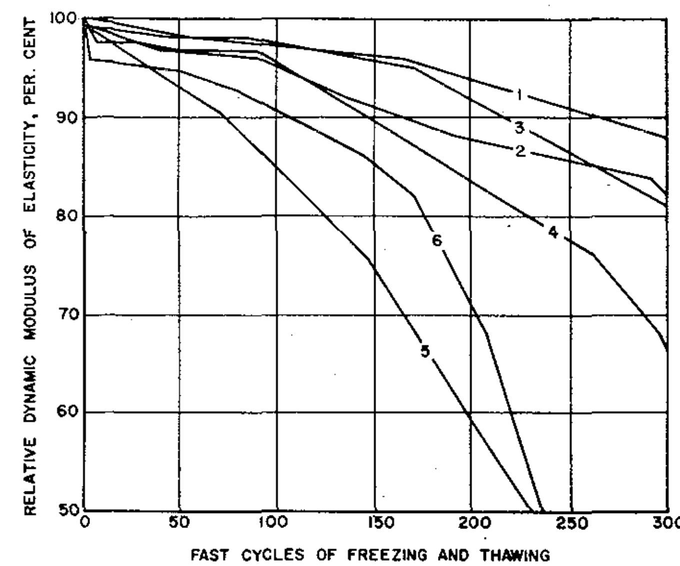
CUMMINGS COVE

GRADATION RANGE OF MATERIAL



	Type	Sc	Rc	Sc/Rc	SOURCE
1	Fine aggr.	10	157	0.064	Bethel
2	Coarse aggr.	14	132	0.106	Bethel
3	Fine aggr.	14	125	0.112	Cummings Cove
4	Fine aggr.	14	120	0.117	Dennysville

CHEMICAL AGGREGATE – ALKALI REACTIVITY TEST REPORT



	AGGREGATE COARSE	FINE	D.F.E. 300 CYCLES
1	Std. Trap Rock	Bethel	88
2	Std. Trap Rock	Dennysville	82
3	Shackford Hd.	Shackford Hd.	81
4	Std. Trap Rock	Cummings Cove	66
5	Bethel	Bethel	38
6	Bethel	Std. Qtz. Sand	39

RESISTANCE OF CONCRETE BEAMS TO ACCELERATED FREEZING AND THAWING

TABULATION OF PETROGRAPHIC ANALYSES AND ENGINEERING PROPERTIES

	Linear Expansion Coef. x 10-6/°F	Coarse Aggregate Bethel	Coarse Aggregate Shackford Head	Fine Aggregate Bethel	Fine Aggregate Dennysville	Fine Aggregate Cummings Cove	Fine Aggregate Shackford Head
Basic Igneous	3.6 to 4.7	5%	100%	1%	4%	1%	100%
Fine-grained Schists, Argillites and Quartzites	4.3 to 5.2	62%		65%	38%	44%	
Weathered Rocks	5.6	4%		2%	3%	8%	
Granite	4.2	25%		9%	4%	7%	
Feldspar				8%	23%	13%	
Quartz	6.5	4%		15%	25%	25%	
Miscellaneous				trace	3%	2%	
Specific Gravity		2.71	2.86	2.68 to 2.70	2.67	2.67	2.84
Absorption %		0.7	0.2	0.5 to 1.2	0.6	1.0	0.5
Soundness, 5 Cycles $MgSO_4$ % Loss		0.8 to 0.9	2.3	5.2 to 5.4	1.3	15.8	3.2

NOTE:
FOR LOCATION OF MATERIAL SOURCES, SEE PLATE 2-3

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL PROJECT

CONCRETE AGGREGATE CHARACTERISTICS

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-135

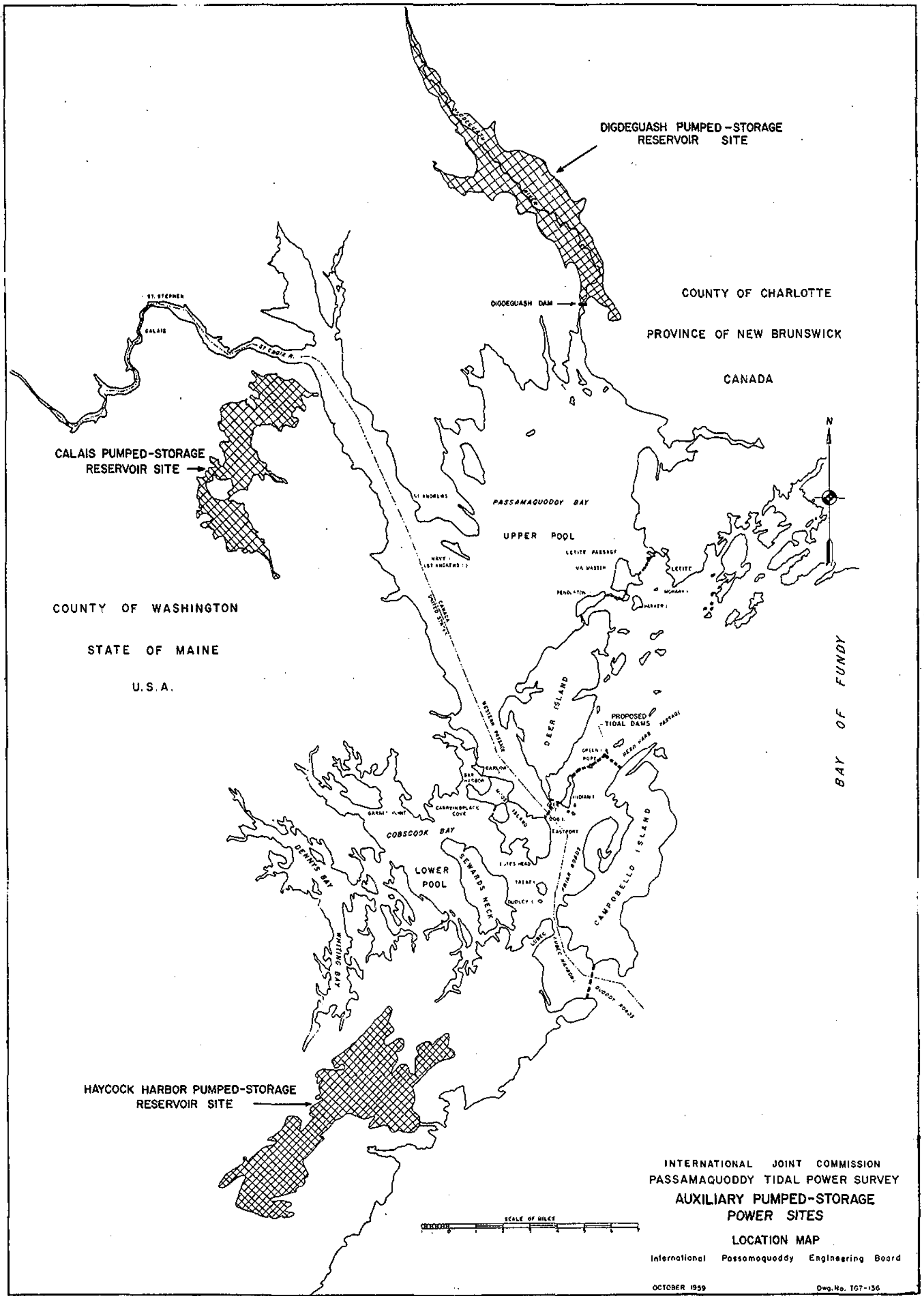
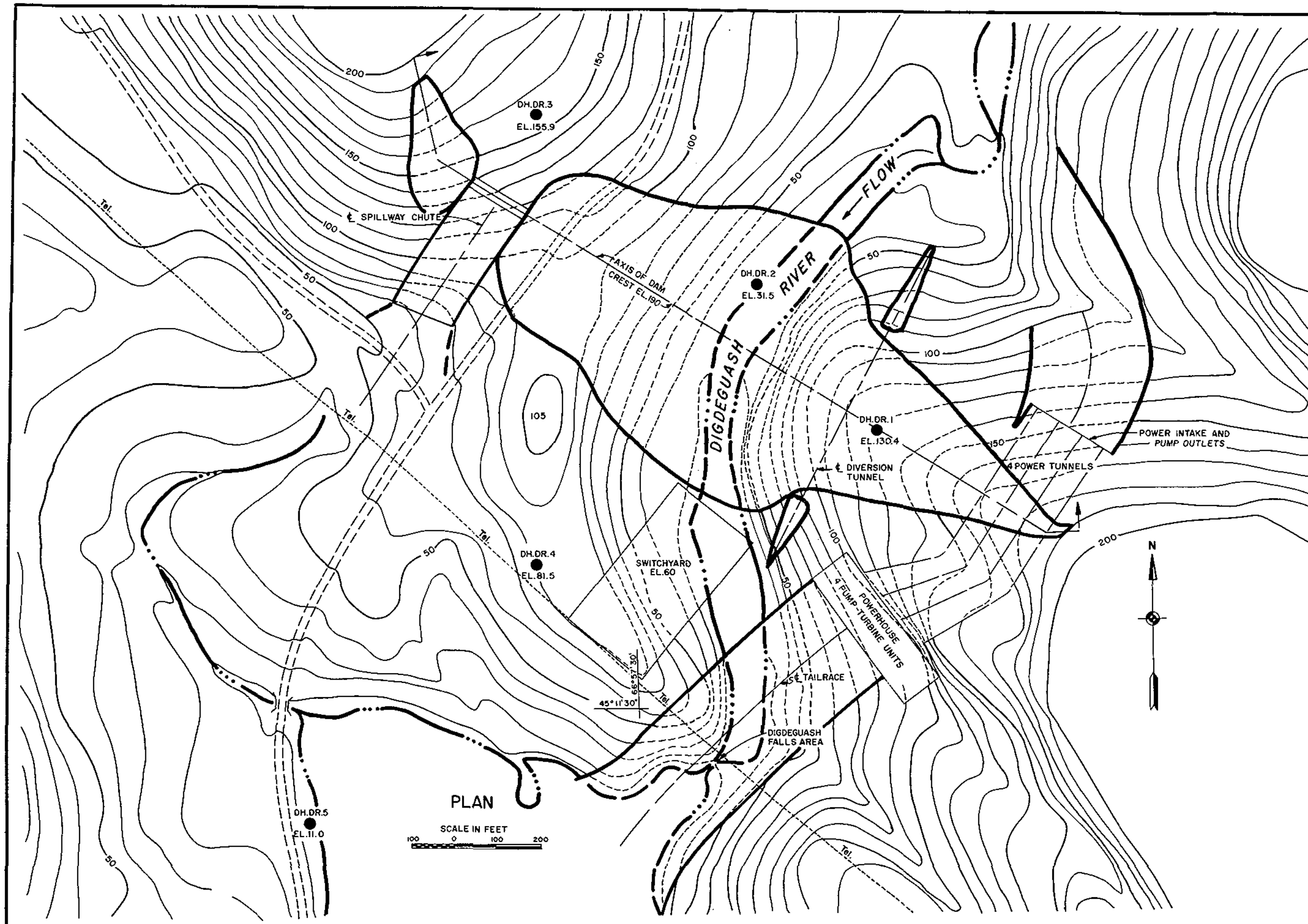
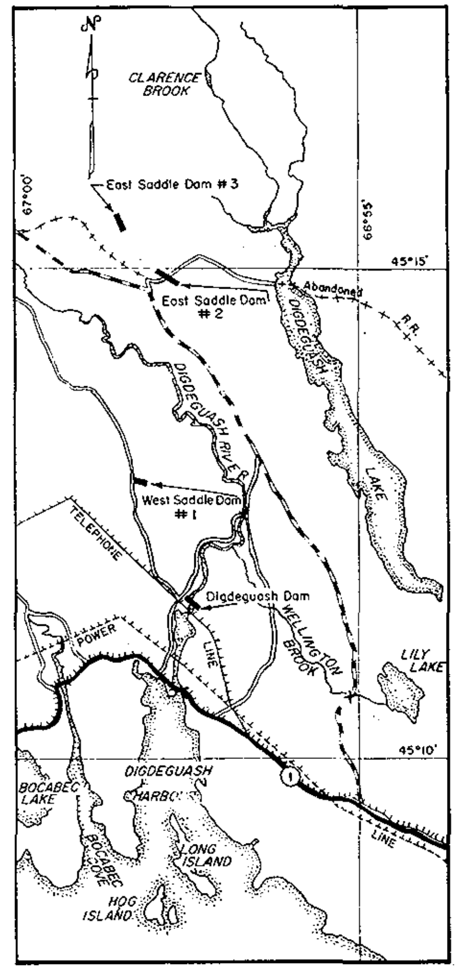

DIGDEGUASH PUMPED-STORAGE
RESERVOIR SITE
DIGDEGUASH DAM
COUNTY OF CHARLOTTE
PROVINCE OF NEW BRUNSWICK
CANADA
N
CALAIS PUMPED-STORAGE
RESERVOIR SITE
CALAIS
ST. STEPHEN
PASSAMAQUODDY BAY
UPPER POOL
LETITE
COUNTY OF WASHINGTON
STATE OF MAINE
U.S.A.
DEER ISLAND
PROPOSED
TIDAL DAMS
BAY OF FUNDY
COBSCOOK BAY
LOWER
POOL
SEWARDS NECK
DENNYS BAY
WHITING BAY
EASTPORT
LUBEC
CAMPOBELLO ISLAND
HAYCOCK HARBOR PUMPED-STORAGE
RESERVOIR SITE
SCALE OF MILES
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
AUXILIARY PUMPED-STORAGE
POWER SITES
LOCATION MAP
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-136

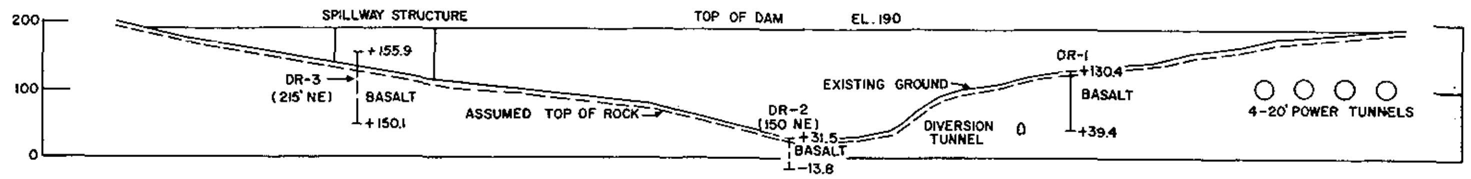
PLATE 2-40





VICINITY MAP

SCALE IN MILES



PROFILE ALONG ℄ OF DAM

HORIZONTAL SCALE IN FEET

NOTES:

ALL ELEVATIONS ARE REFERRED TO MEAN SEA LEVEL.
DRILL HOLES SHOWN THUS ● DR-5

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

DIGDEGUASH DEVELOPMENT

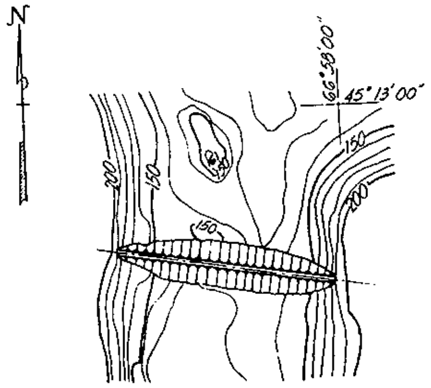
PLAN AND PROFILE
MAIN DAM

International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-137

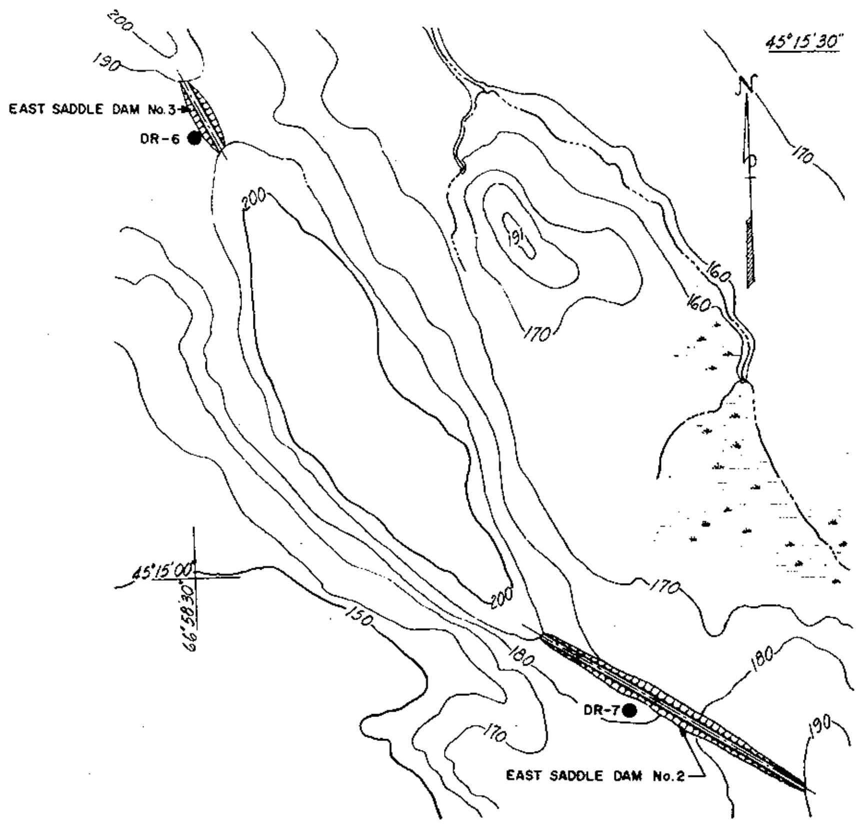
PLATE 2-41



WEST SADDLE DAM No. 1

SCALE IN FEET

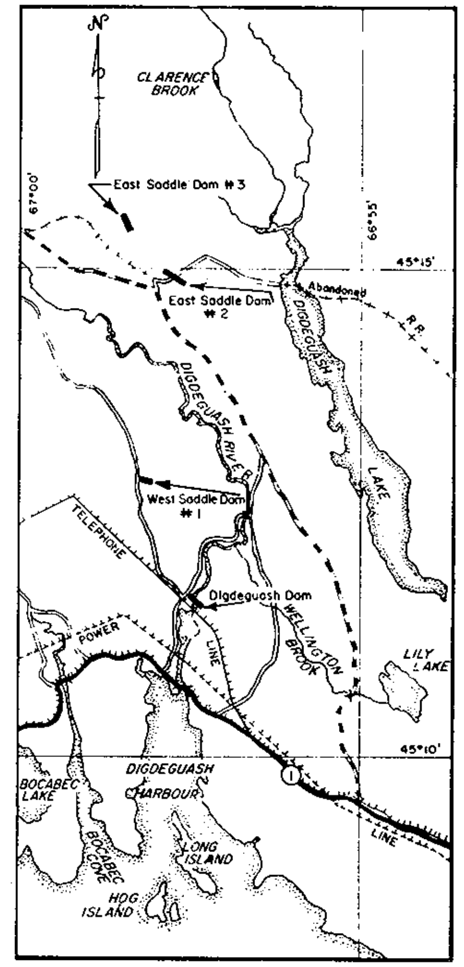
200 0 200 400 600



EAST SADDLE DAMS No. 2 AND No. 3

SCALE IN FEET

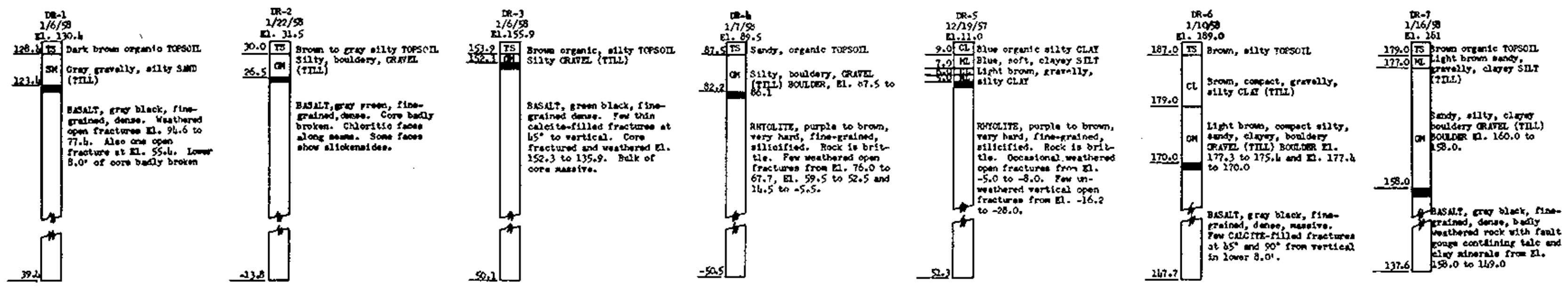
200 0 200 400 600



VICINITY MAP

SCALE IN MILES

1 0 1 2 3



Notes:

All elevations are referred to mean sea level.

Drill holes shown thus ● DR-6.

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

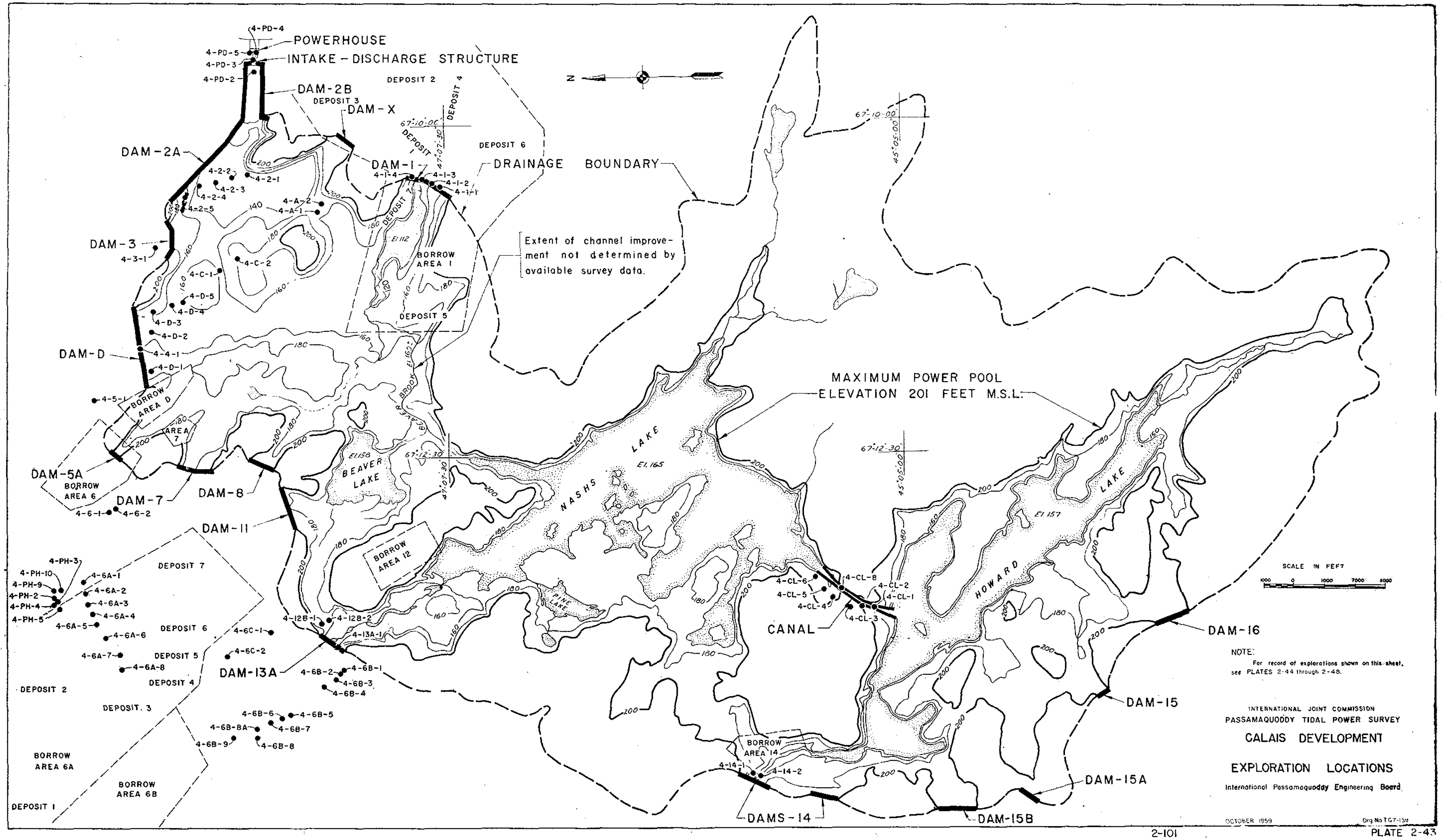
DIGDEGUASH DEVELOPMENT

RECORD OF EXPLORATION AND SADDLE DAM PLANS

International Passamaquoddy Engineering Board

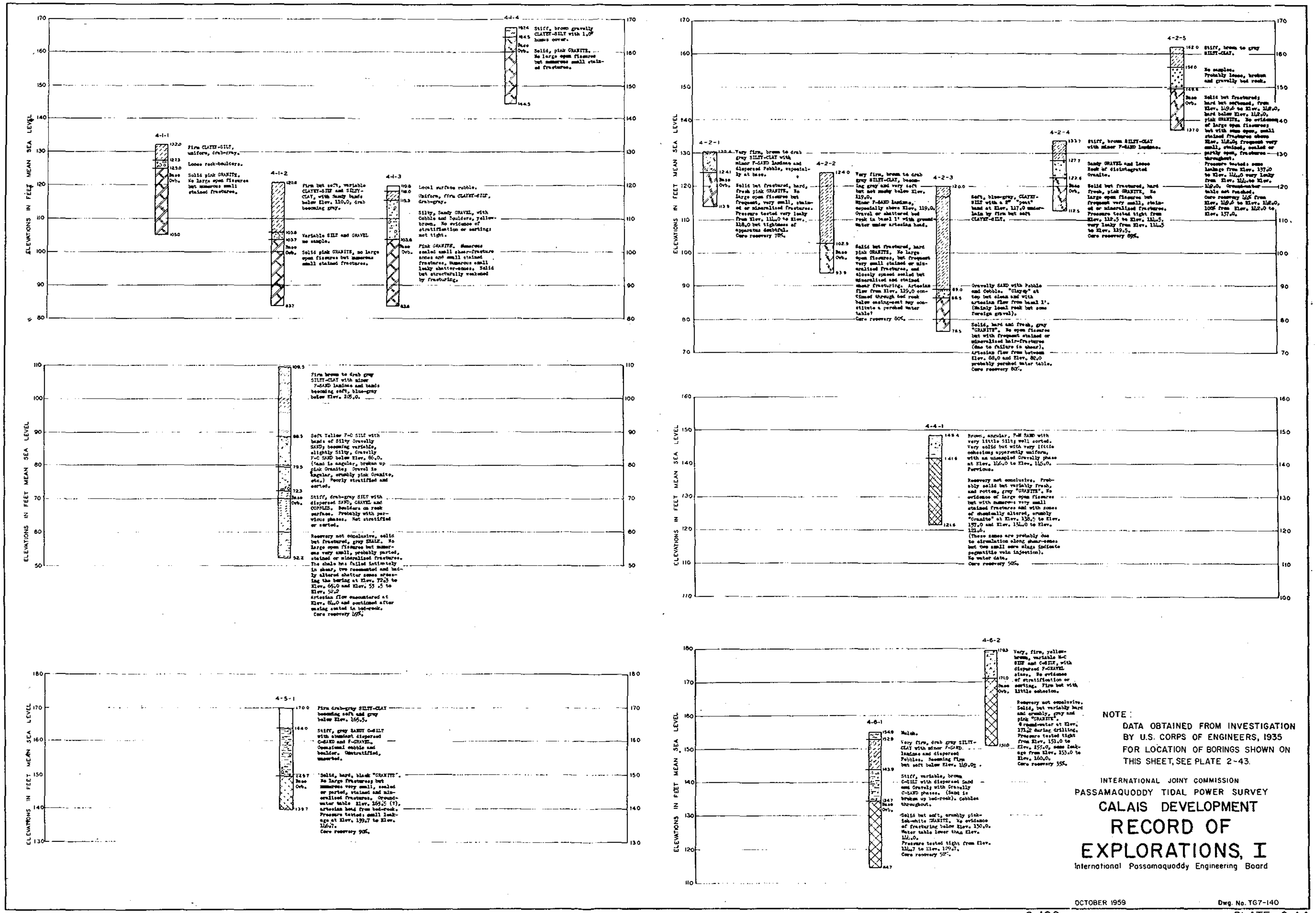
OCTOBER 1959

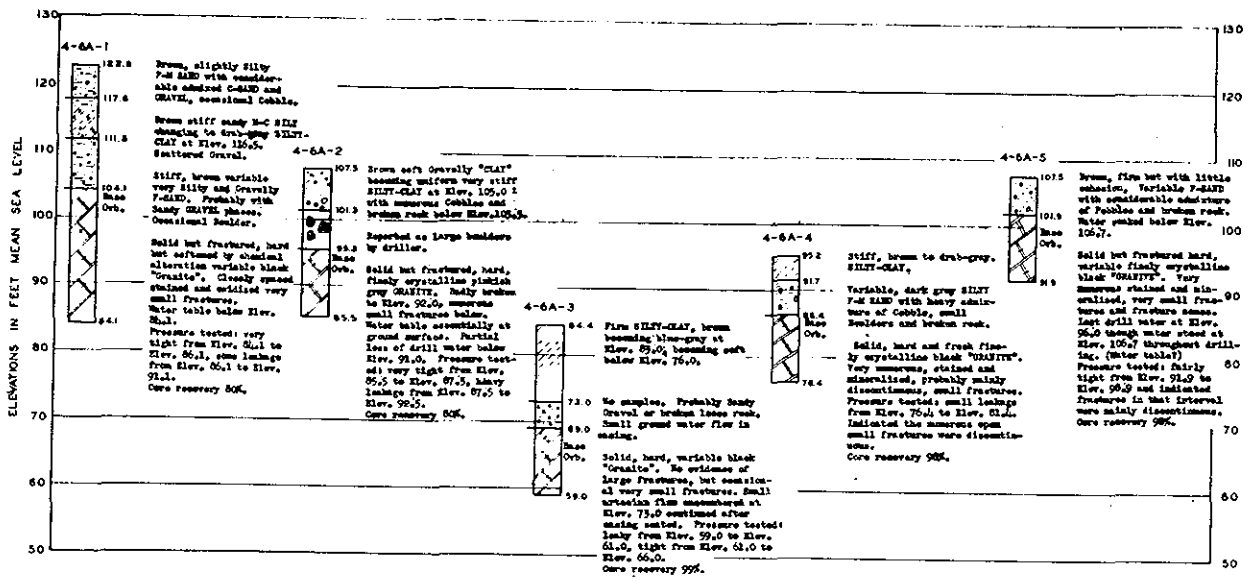
Dwg. No. TG7-138

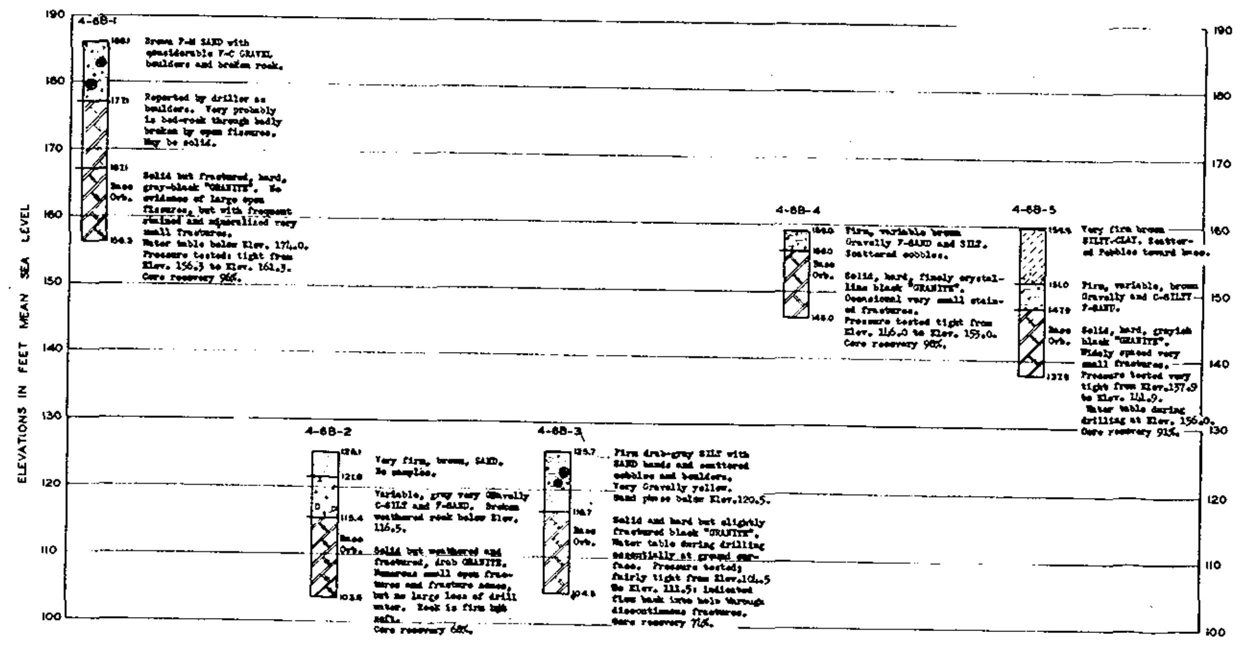


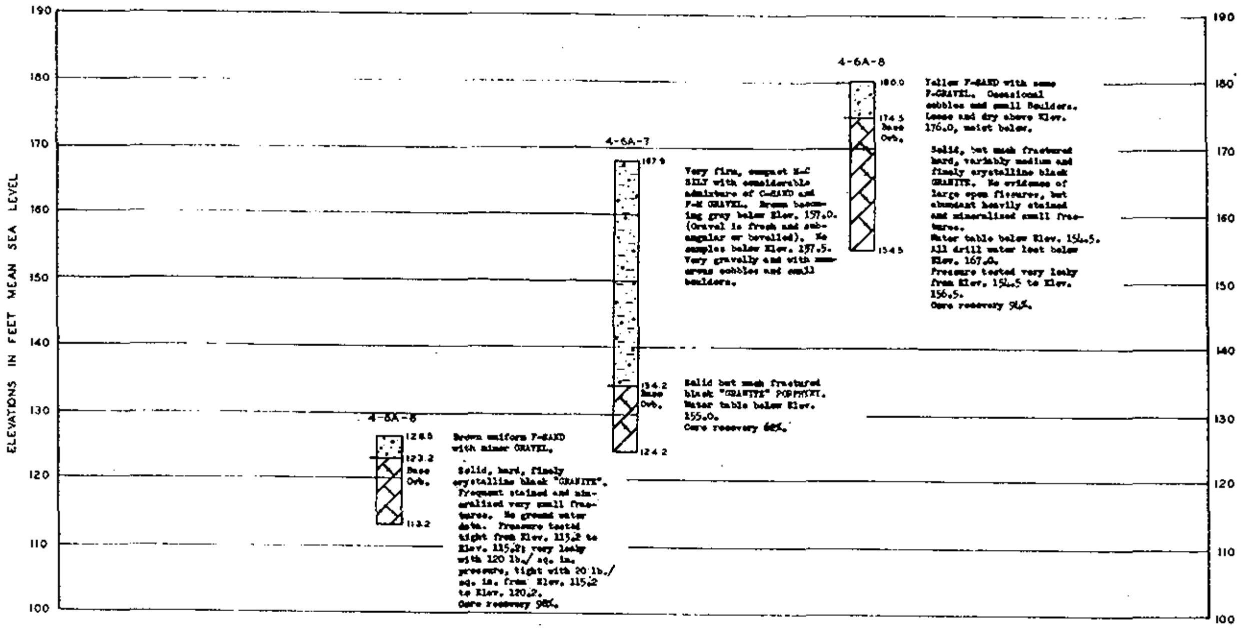
POWERHOUSE
INTAKE - DISCHARGE STRUCTURE
DAM-2B
DAM-X
DAM-2A
DAM-1
DRAINAGE BOUNDARY
DAM-3
DAM-D
DAM-5A
DAM-7
DAM-8
DAM-11
DAM-13A
BORROW AREA 1
BORROW AREA D
BORROW AREA 6
BORROW AREA 12
BORROW AREA 14
BORROW AREA 6A
BORROW AREA 6B
DEPOSIT 1
DEPOSIT 2
DEPOSIT 3
DEPOSIT 4
DEPOSIT 5
DEPOSIT 6
DEPOSIT 7
Extent of channel improvement not determined by available survey data.
BEAVER LAKE
NASHS LAKE El. 165
PINE LAKE
HOWARD LAKE El. 157
MAXIMUM POWER POOL ELEVATION 201 FEET M.S.L.
CANAL
DAMS-14
DAM-15
DAM-15A
DAM-15B
DAM-16
SCALE IN FEET
NOTE:
For record of explorations shown on this sheet, see PLATES 2-44 through 2-48.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
CALAIS DEVELOPMENT
EXPLORATION LOCATIONS
International Passamaquoddy Engineering Board
OCTOBER 1959

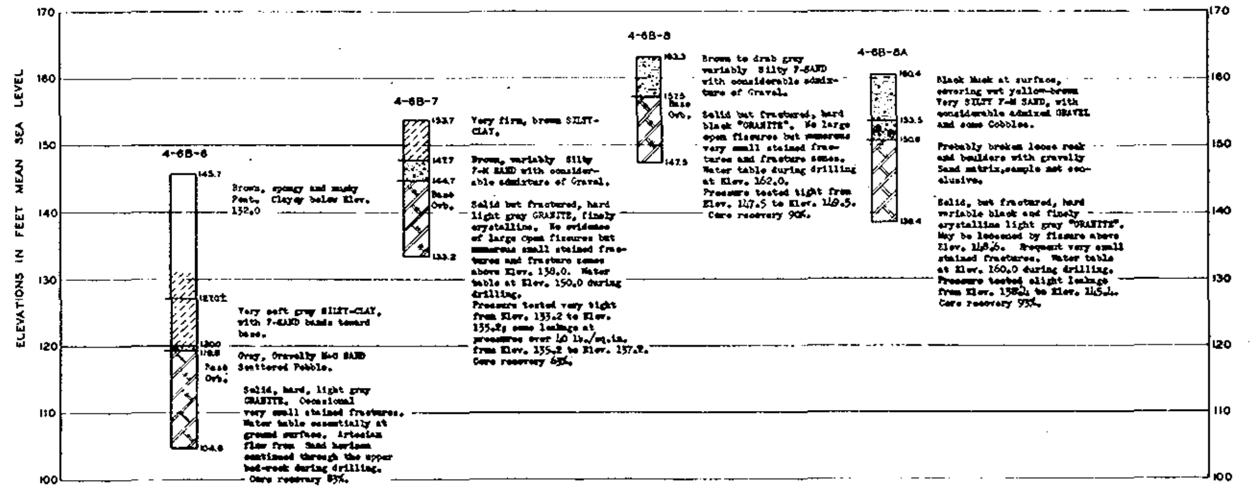
PLATE 2-43


ELEVATIONS IN FEET MEAN SEA LEVEL
4-1-1
4-1-2
4-1-3
4-1-4
4-2-1
4-2-2
4-2-3
4-2-4
4-2-5
4-4-1
4-5-1
4-6-1
4-6-2
NOTE:
DATA OBTAINED FROM INVESTIGATION BY U.S. CORPS OF ENGINEERS, 1935
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET, SEE PLATE 2-43.
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
CALAIS DEVELOPMENT
RECORD OF EXPLORATIONS, I
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-140









NOTE:
DATA OBTAINED FROM INVESTIGATION
BY U.S. CORPS OF ENGINEERS, 1935
FOR LOCATION OF BORINGS SHOWN ON
THIS SHEET, SEE PLATE 2-43.

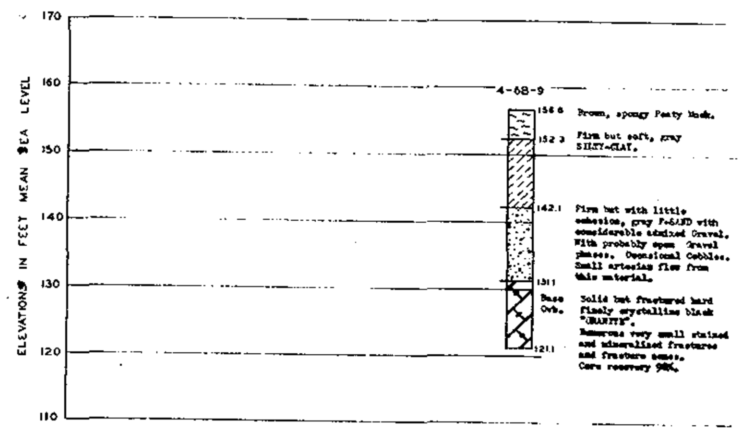
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

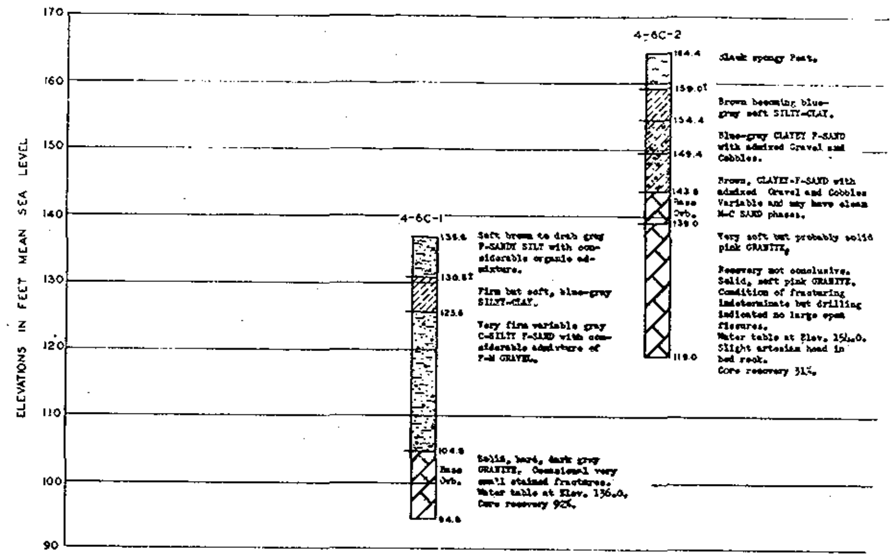
CALAIS DEVELOPMENT
RECORD OF EXPLORATIONS, II

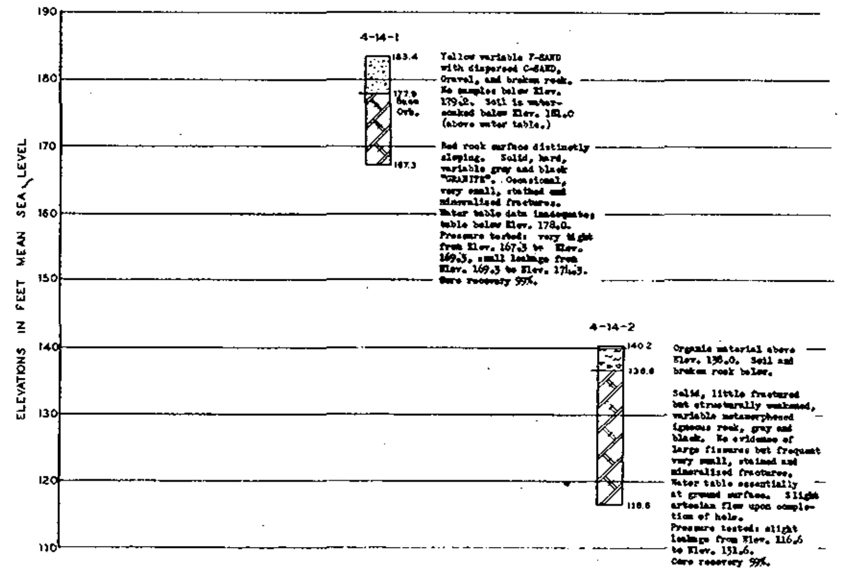
International Passamaquoddy Engineering Board

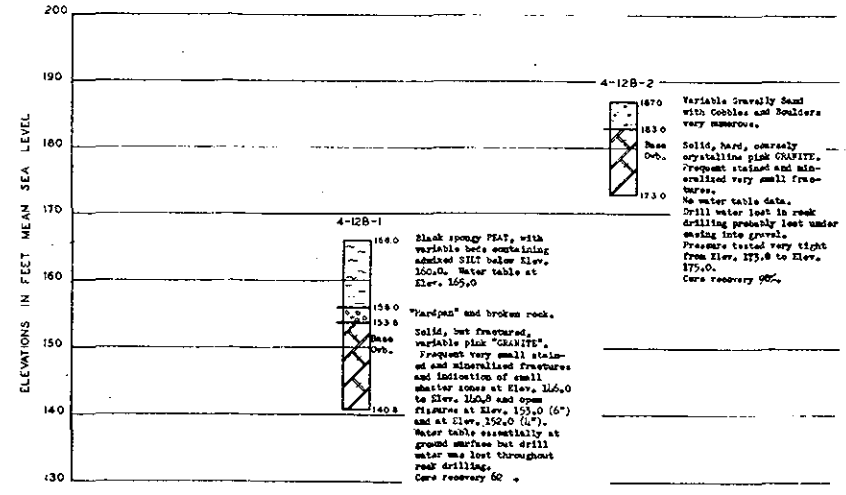
OCTOBER 1959

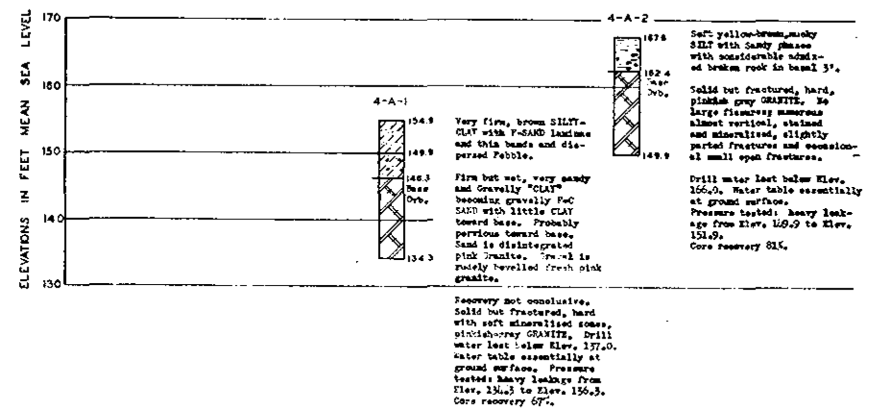
Dwg. No. TG7-141

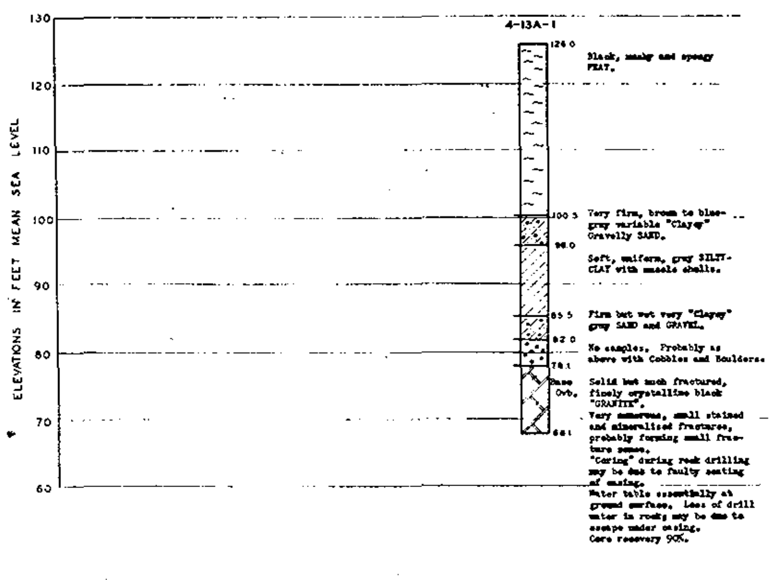












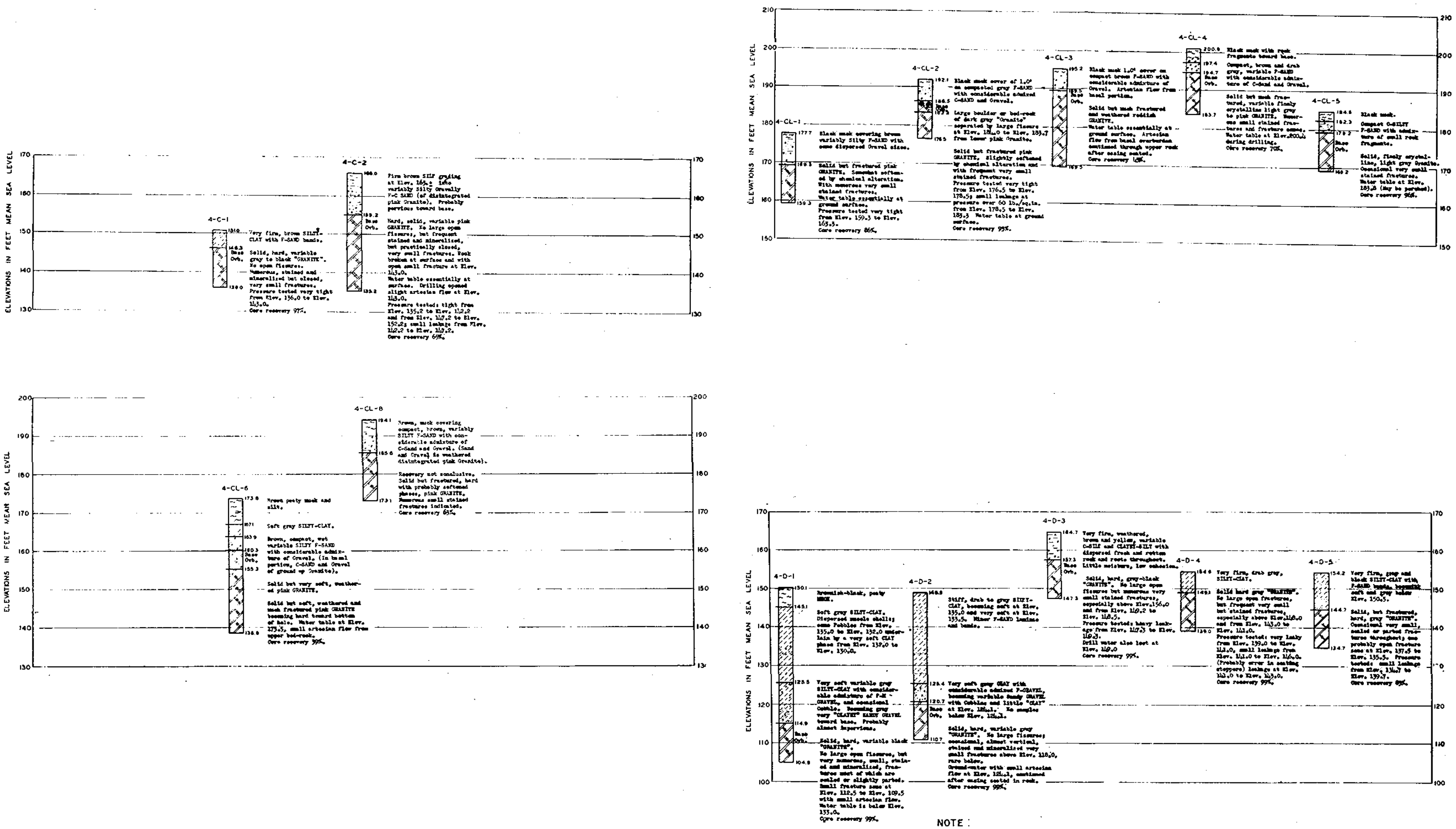
NOTE:
DATA OBTAINED FROM INVESTIGATION BY U.S. CORPS OF ENGINEERS, 1935
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET, SEE PLATE 2-43.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

CALAIS DEVELOPMENT
RECORD OF EXPLORATIONS, III

International Passamaquoddy Engineering Board

OCTOBER 1959   Dwg. No TG7-142

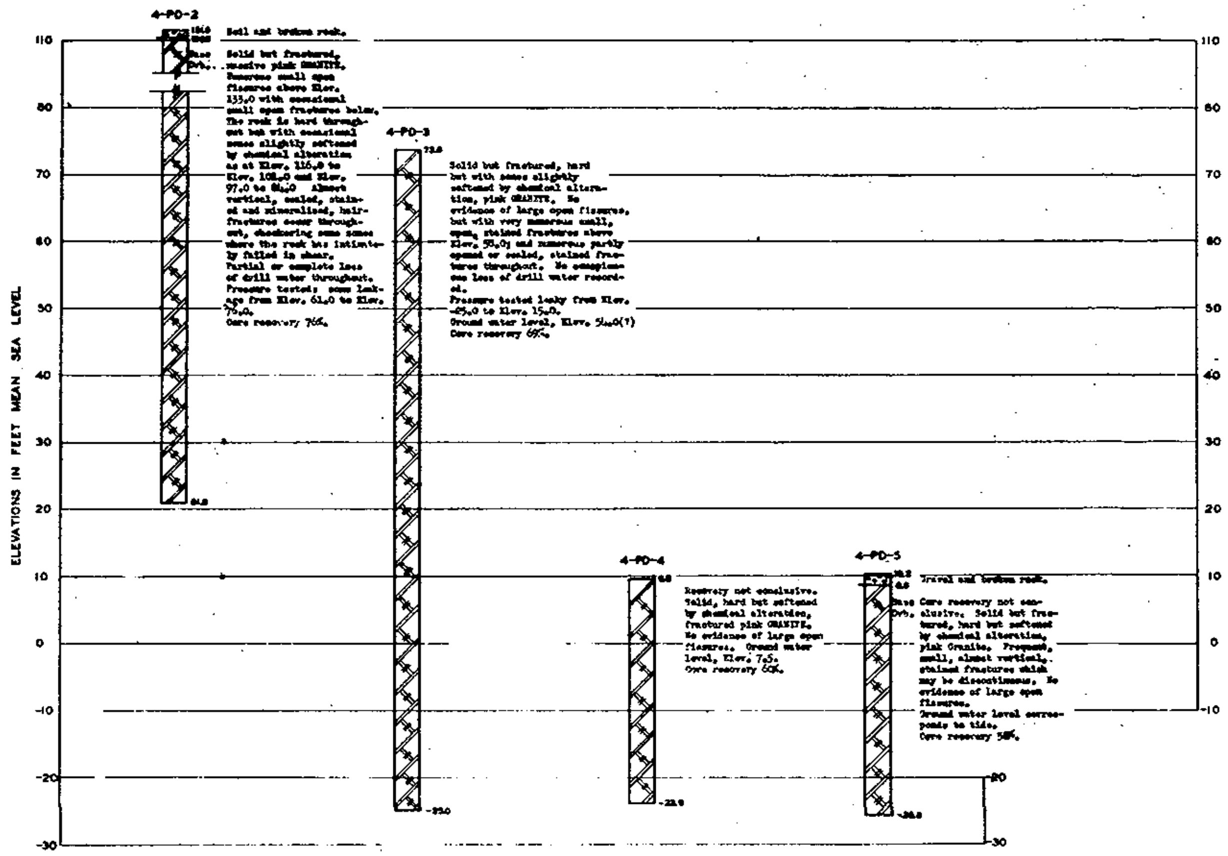


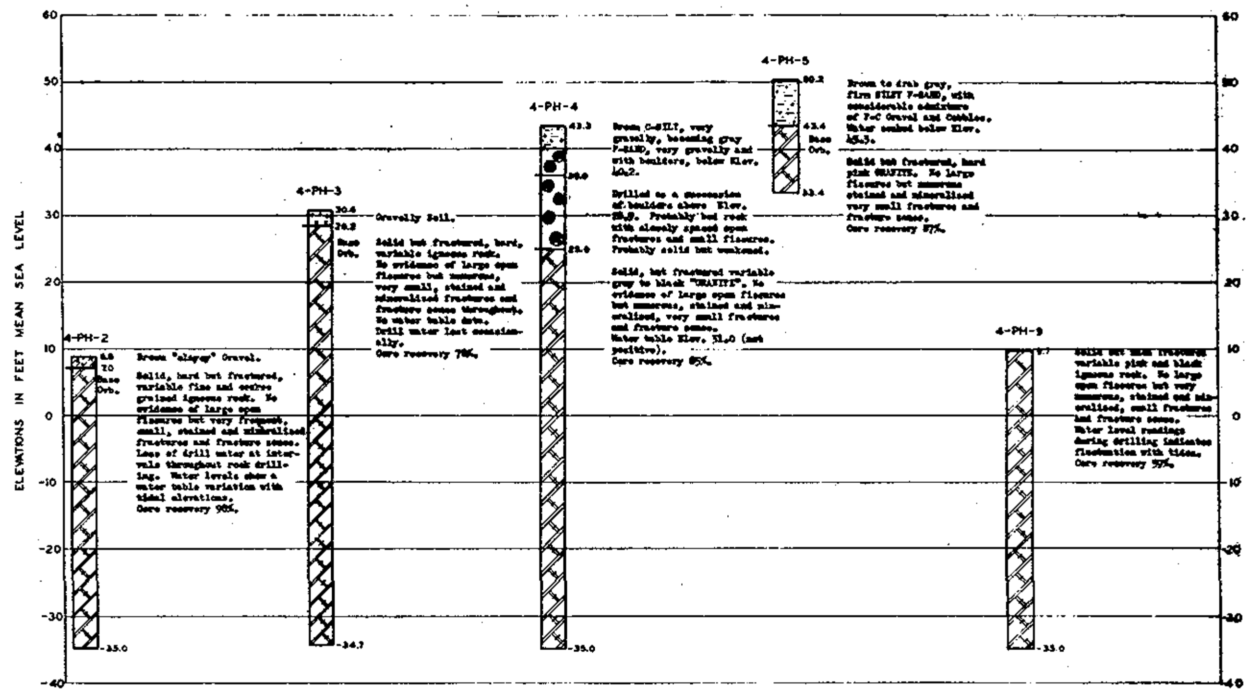
NOTE:
DATA OBTAINED FROM INVESTIGATION BY U.S. CORPS OF ENGINEERS, 1935
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET SEE PLATE 2-43.

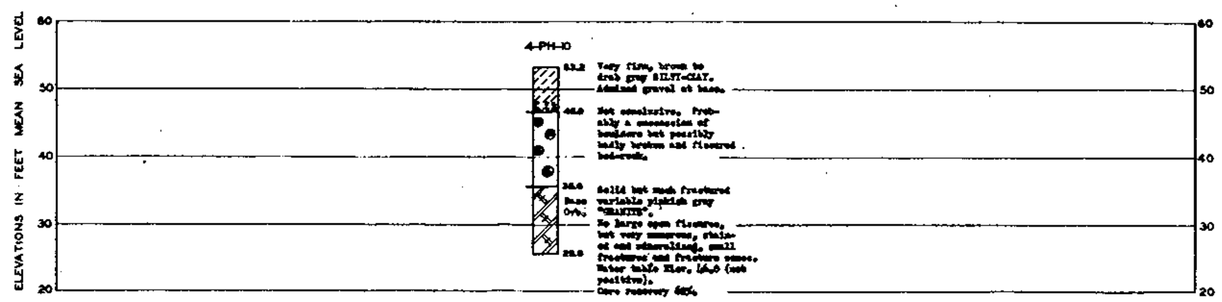
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
CALAIS DEVELOPMENT
RECORD OF EXPLORATIONS, IV
International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-143







NOTE:
DATA OBTAINED FROM INVESTIGATION BY U.S. CORPS OF ENGINEERS 1935
FOR LOCATION OF BORINGS SHOWN ON THIS SHEET SEE PLATE 2-43.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

CALAIS DEVELOPMENT

RECORD OF EXPLORATIONS, V

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-144

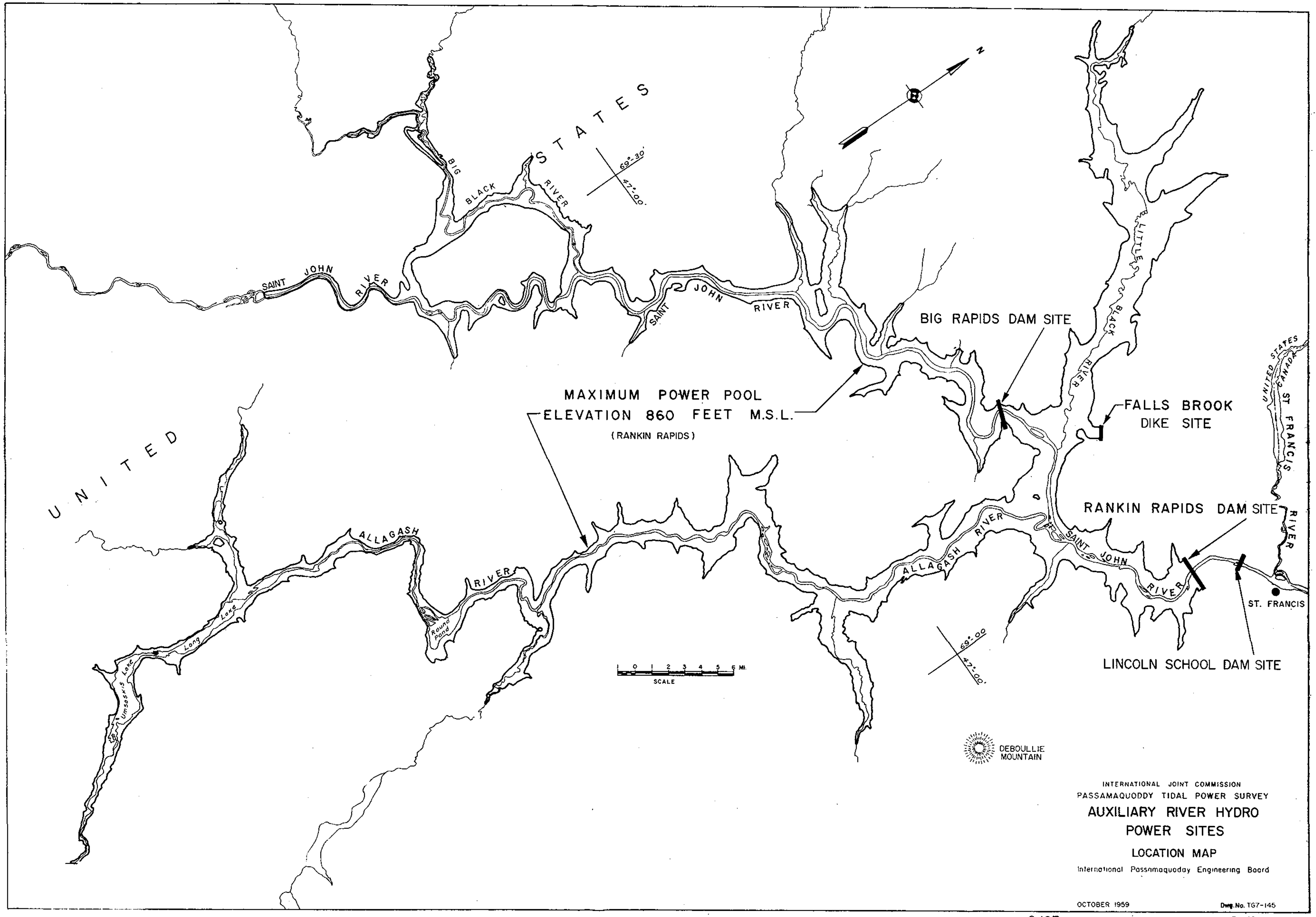
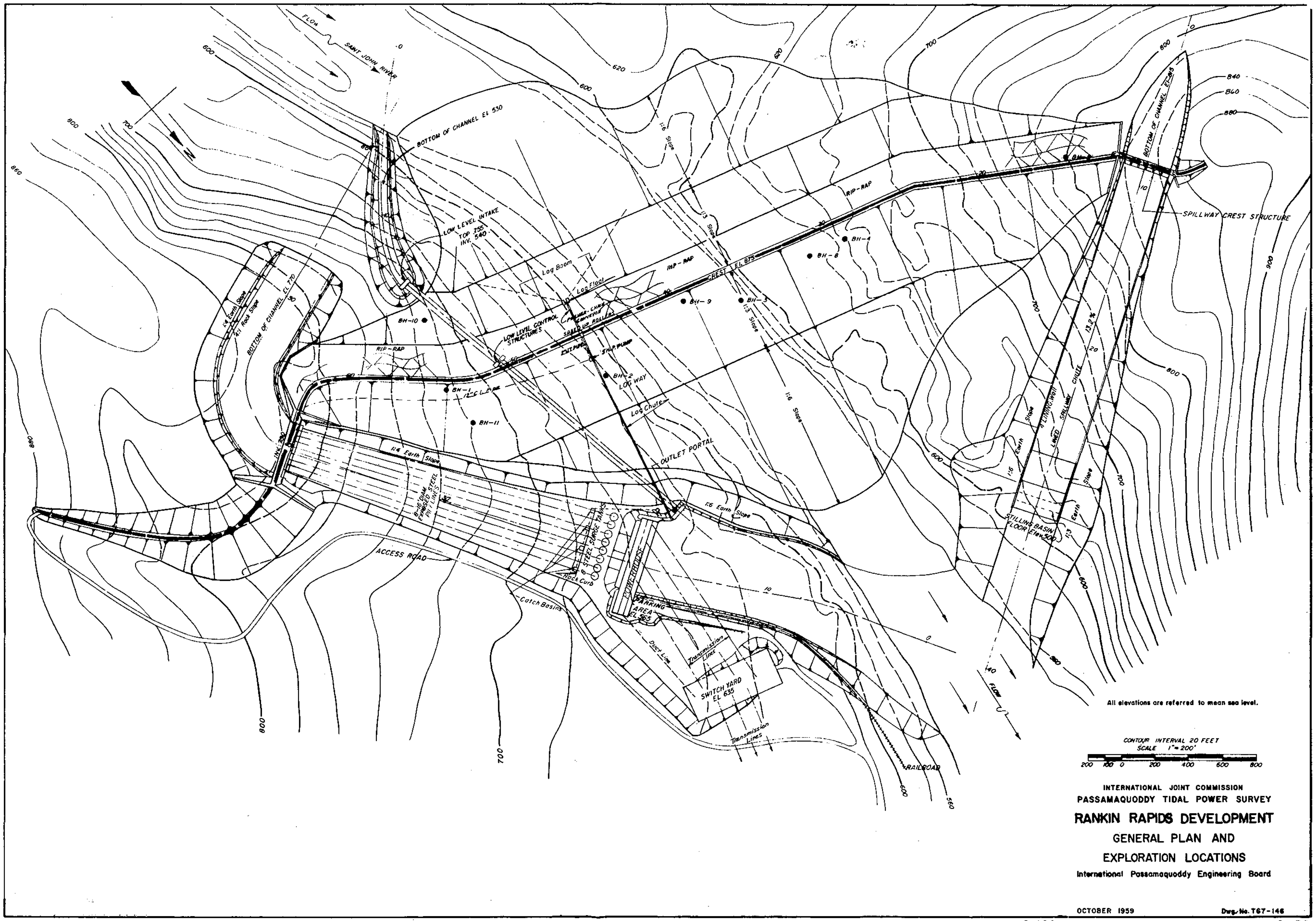

UNITED STATES
SAINT JOHN RIVER
BIG BLACK RIVER
LITTLE BLACK RIVER
ALLAGASH RIVER
Long Lake
Umsaskis Lake
Round Pond
69°30'
47°00'
69°00'
47°00'
N
BIG RAPIDS DAM SITE
FALLS BROOK DIKE SITE
MAXIMUM POWER POOL
ELEVATION 860 FEET M.S.L.
(RANKIN RAPIDS)
RANKIN RAPIDS DAM SITE
LINCOLN SCHOOL DAM SITE
ST. FRANCIS
ST. FRANCIS RIVER
UNITED STATES
CANADA
SCALE
1 0 1 2 3 4 5 6 MI.
DEBOULLIE MOUNTAIN
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
AUXILIARY RIVER HYDRO
POWER SITES
LOCATION MAP
International Passamaquoddy Engineering Board
OCTOBER 1959
Dwg. No. TG7-145

PLATE 2-49



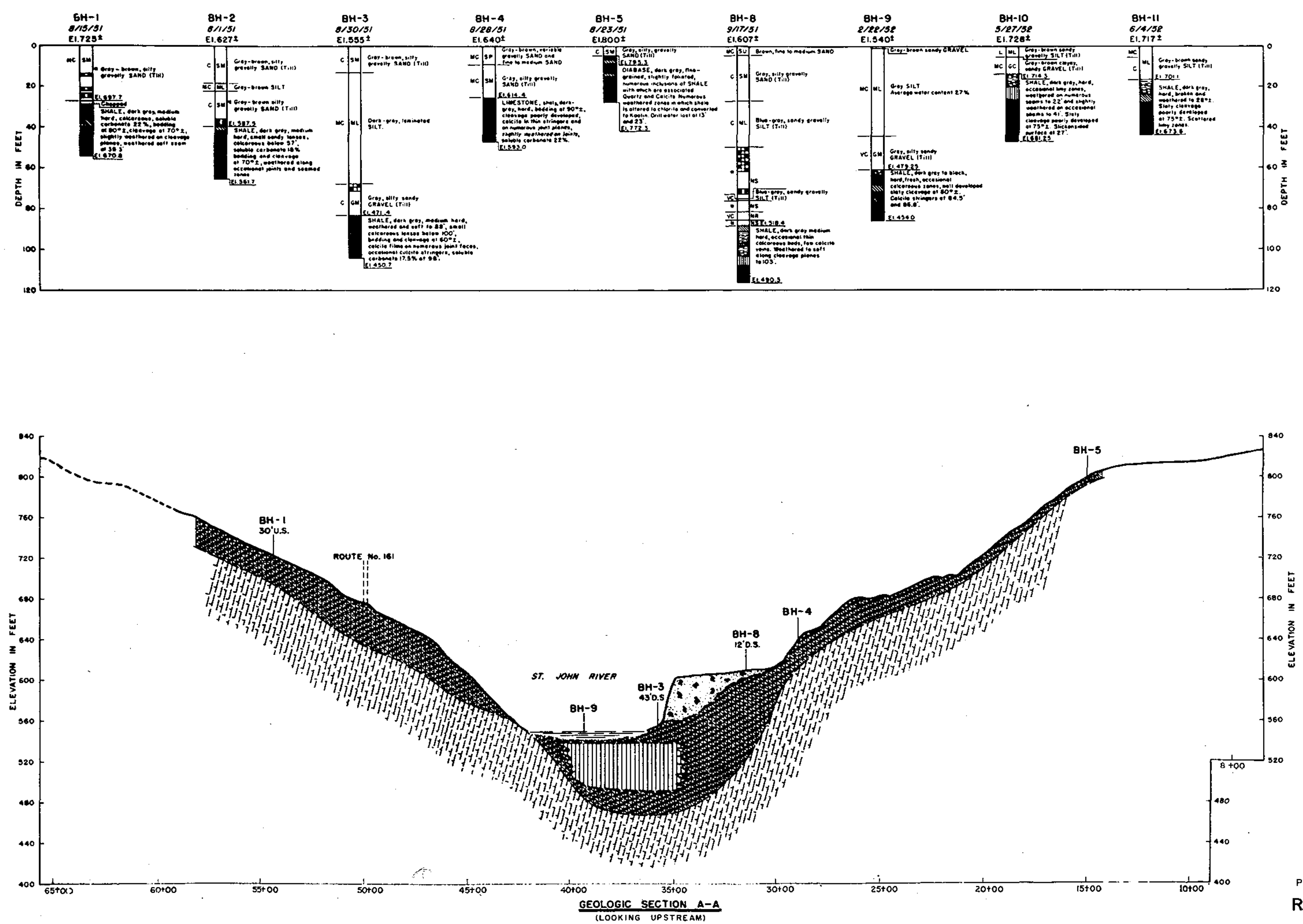
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

GENERAL PLAN AND
EXPLORATION LOCATIONS

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. T67-146



GEOLOGIC SECTION A-A
(LOOKING UPSTREAM)

LEGEND FOR GRAPHIC LOGS

BH-1	Test boring number.
12/9/52	Month/day/year exploration completed
El. 521	Elevation of ground surface.
	Ground water table at time of exploration.
GM	Department of the Army Uniform Soil Classification System Symbol.
NR	No satisfactory soil samples recovered.
NS	Not sampled.
VC	Symbol for compaction in accordance with legend shown below. Compaction determined by number of blows per foot of penetration of sample spoon.
*	Blow count not recorded in error or not considered representative.
	Boulder
	Boulders (continuous or nested).
El. 450.2	Elevation of bedrock surface.
	Rock core recovery 0-25%.
	Rock core recovery 25-50%.
	Rock core recovery 50-75%.
	Rock core recovery 75-90%.
	Rock core recovery 90-100%.
El. 426.4	Elevation of bottom of exploration.

COMPACTION SYMBOLS

VL	Very loose overburden
L	Loose overburden
MC	Medium compact overburden
C	Compact overburden
VC	Very compact overburden

LEGEND FOR GEOLOGIC SECTION

- Stratified Terrace SANDS and GRAVELS
- Medium Compact SILT (30 blows per foot is representative of penetration resistance using a 2½ inch O.D. sample tube driven by 350# hammer falling about 18 inches).
- TILL, medium compact to very compact, silty gravelly SAND, sandy gravelly SILT, or clayey sandy GRAVEL.
- Calcareous SHALE or shaly LIMESTONE showing approximate dip of cleavage.

NOTES:—

For location of exploration and geologic section see plate 2-50.

Borings BH-6 and BH-7 not shown graphically were made during site selection studies at Golden Rapids approximately 2 miles upstream.

All elevations are referred to mean sea level.

INTERNATIONAL JOINT COMMISSION

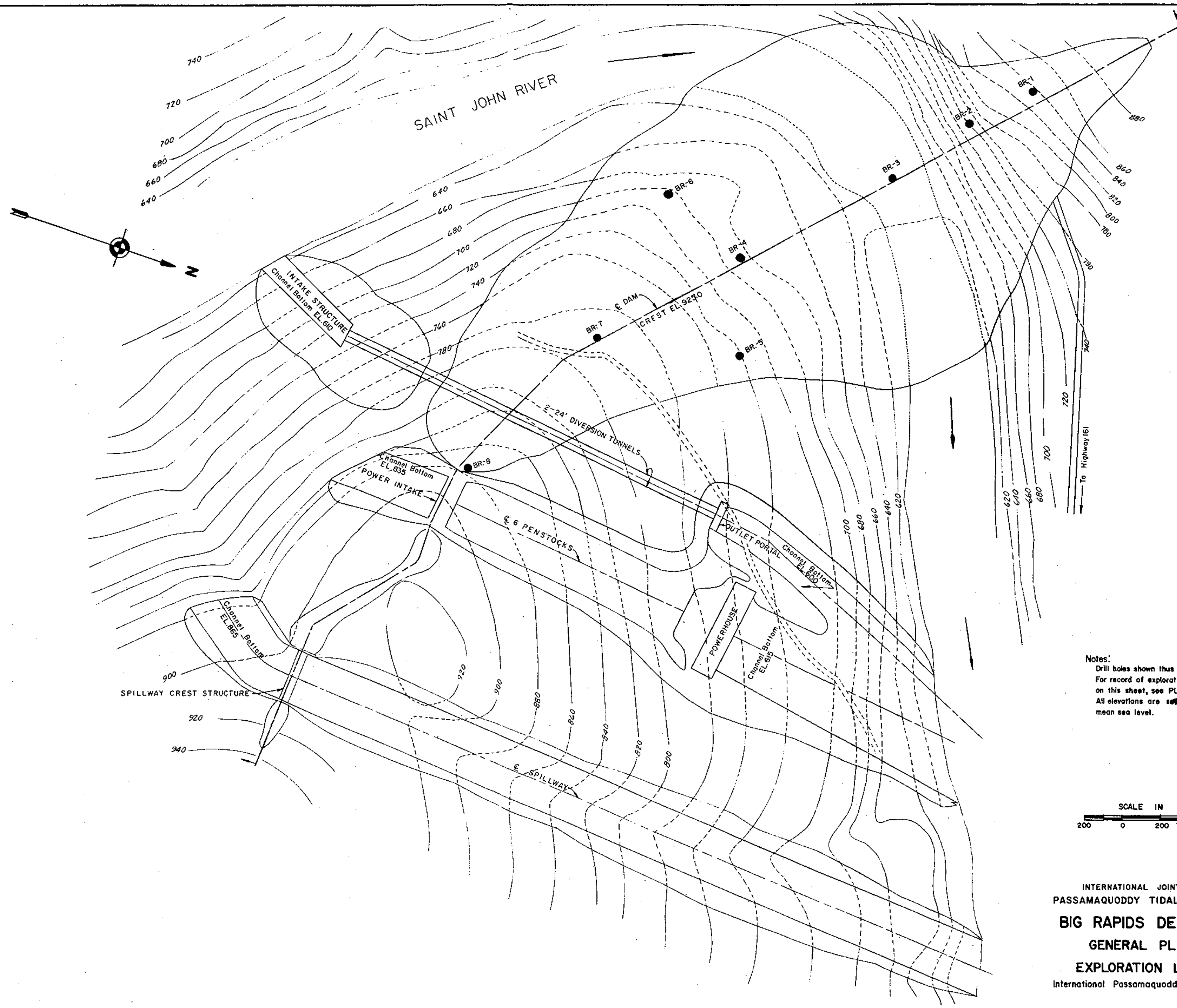
PASSAMAQUODDY TIDAL POWER SURVEY

RANKIN RAPIDS DEVELOPMENT

RECORD OF EXPLORATION AND GEOLOGIC PROFILE

International Passamaquoddy Engineering Board

OCTOBER 1959 Dwg. No. TG7-147



Notes:
Drill holes shown thus ●BR-8.
For record of explorations shown on this sheet, see PLATE 2-53
All elevations are referred to mean sea level.

SCALE IN FEET
200 0 200 400 600

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

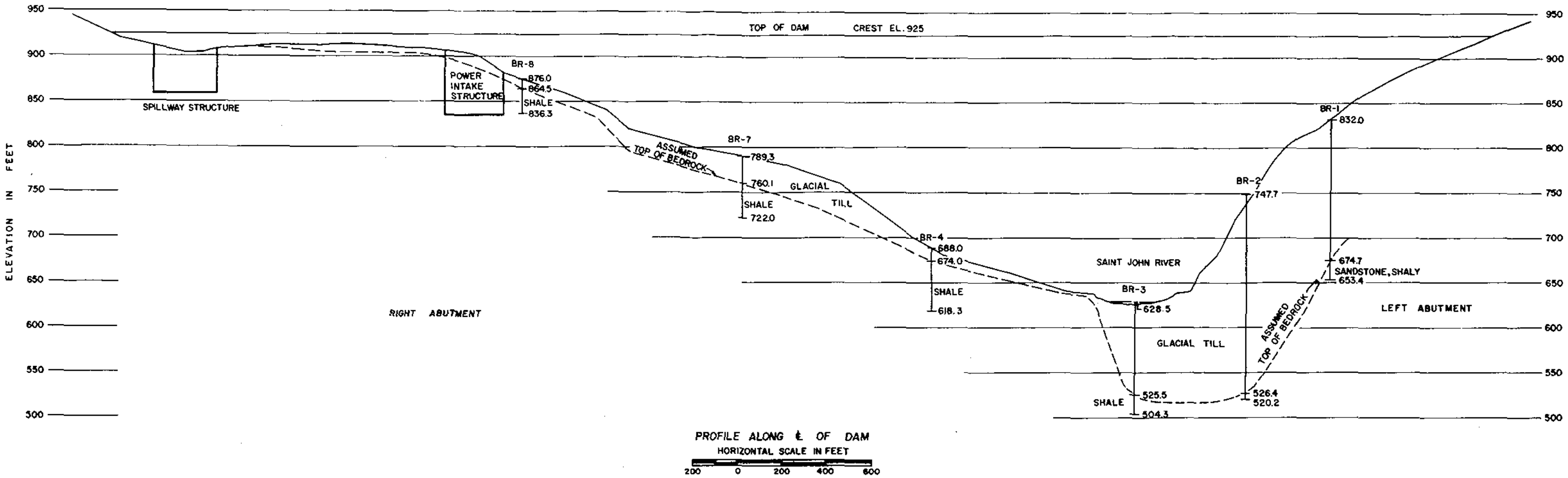
BIG RAPIDS DEVELOPMENT
GENERAL PLAN AND EXPLORATION LOCATIONS

International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-148

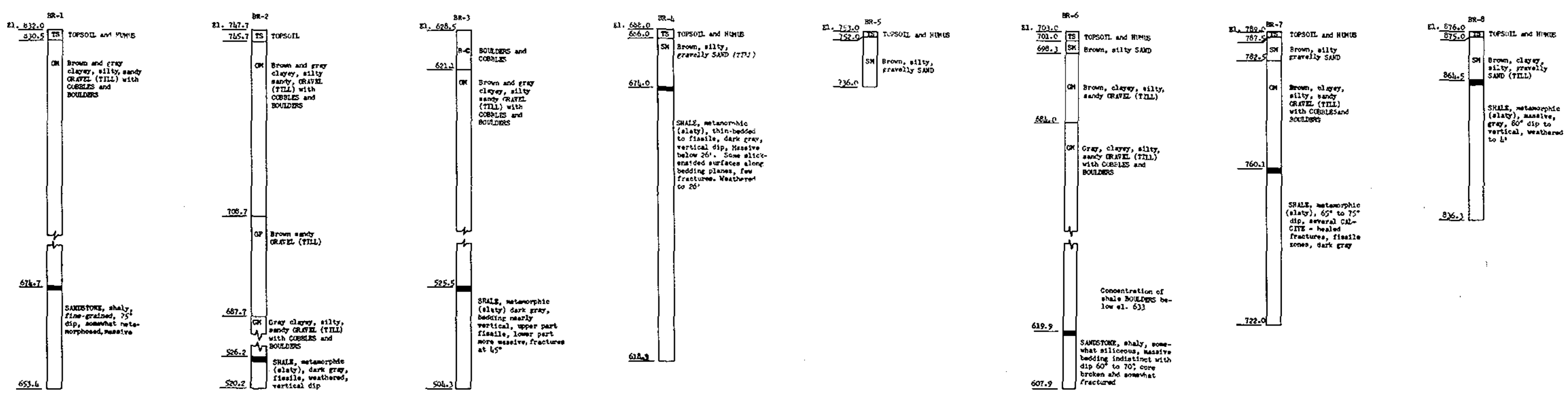
PLATE 2-52



PROFILE ALONG ℄ OF DAM

HORIZONTAL SCALE IN FEET

200 0 200 400 600



Notes:

For location of explorations and profile shown on this sheet see PLATE 2-52.
All elevations are referred to mean sea level.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

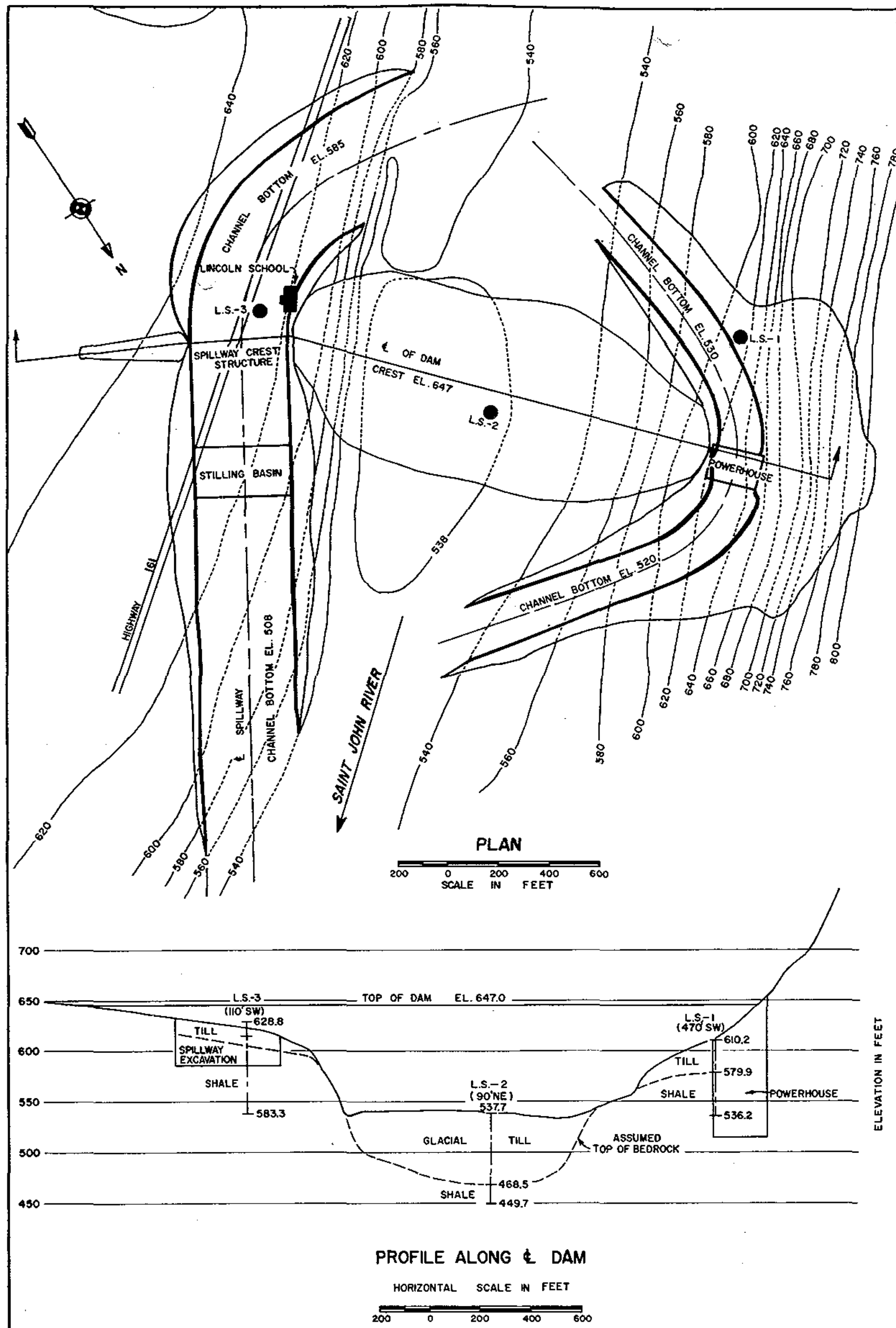
BIG RAPIDS DEVELOPMENT

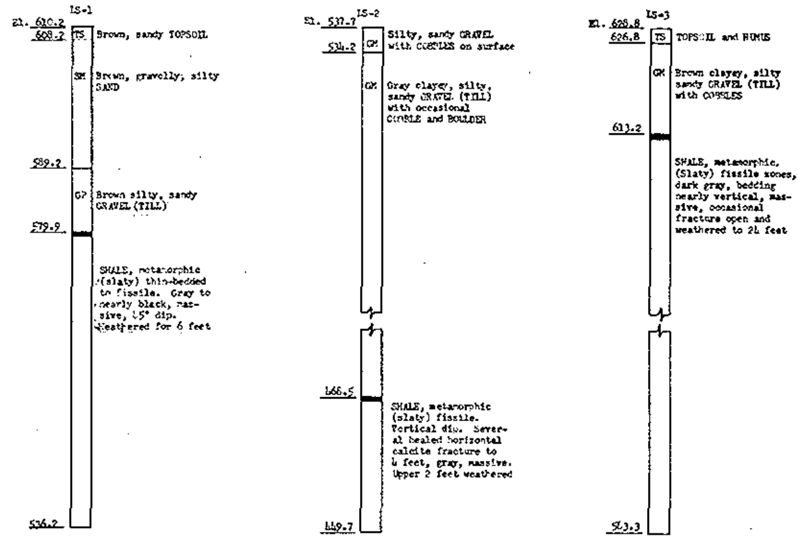
RECORD OF EXPLORATION AND GEOLOGIC PROFILE

International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-149





Notes:

All elevations are referred to mean sea level.
Drill holes shown thus ● LS-3.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

LINCOLN SCHOOL DEVELOPMENT

PLAN, PROFILE AND RECORD OF EXPLORATION

International Passamaquoddy Engineering Board

OCTOBER 1959

Dwg. No. TG7-150

REPORT TO

INTERNATIONAL JOINT COMMISSION

ON

INVESTIGATION OF INTERNATIONAL

PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 3

OBSERVATION AND PREDICTION OF TIDES

BY

INTERNATIONAL PASSAMAQUODDY

ENGINEERING BOARD

OTTAWA, ONTARIO
WASHINGTON, D. C.

OCTOBER 1959

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 3

OBSERVATION AND PREDICTION OF TIDES

CONTENTS

APPENDIX 3

CONTENTS - Continued

APPENDIX 3

LIST OF TABLES

APPENDIX 3

LIST OF PLATES

APPENDIX 3

LIST OF PLATES (Continued)

INTERNATIONAL PASSAMAQUODDY
ENGINEERING BOARD

INVESTIGATION OF INTERNATIONAL
PASSAMAQUODDY TIDAL POWER PROJECT

APPENDIX 3

OBSERVATION AND PREDICTION OF TIDES

3-01 PURPOSE

An accurate knowledge of the tides and currents was required for the planning of the proposed international Passamaquoddy tidal power project. A knowledge of tides and currents was needed for (a) reducing soundings to a common datum to prepare maps of under-water areas, (b) planning deep water drilling operations and reducing the results to a common datum, (c) setting the top levels of all tidal structures, (d) setting of gates and turbines, (e) design of the tidal dams, (f) estimating the power from the tidal power project, and (g) estimating the effect of the proposed tidal power project on the tides in the region.

3-02 SCOPE

This appendix presents data on tide and current observations for the tidal project area, and the analyses of these data required for the study of the proposed tidal power project.

3-03 PROJECT LOCATION

The proposed international Passamaquoddy tidal power project would be located at Cobscook Bay, Maine, and Passamaquoddy Bay, Maine and New Brunswick, near the mouth of the Bay of Fundy where it opens into the Gulf of Maine, plate 3-1. The continental shelf drops off abruptly on a line oceanward of Cape Cod, Georges Bank, Browns Bank, and Nova Scotia, leaving a shoaled opening about 250 miles wide from Cape Cod to Nova Scotia into the Gulf of Maine. The shore and bottom configuration operate to amplify the tide ranges in the Gulf of Maine over those prevailing on the south shore of Cape Cod and the east shore of Nova Scotia. This can be verified by comparing the mean tide ranges along the shore, the values of which are noted on plate 3-1.

The Bay of Fundy extends north-eastward from the Gulf of Maine. The tides are further increased by its shape, and tide ranges at its head are the greatest in the world. At Eastport, Maine, near the location of the proposed tidal power project, the average tide range is 18.1 feet. The project layout including the location of the major features is shown on plate 3-2.

3-04 OBSERVATION OF TIDE STAGES

a. General. As indicated on plate 3-3, observations of tide stages have been made at numerous locations in the Cobscook-Passamaquoddy Bay area. This work has been principally in connection with navigation (either for hydrographic mapping or tide tables) and to a lesser extent for investigating the possibility of developing a tidal power project.

b. U.S. Coast and Geodetic Survey. The earliest data obtained by the U.S. Coast and Geodetic Survey in the tidal project area was for a one-month period in 1841, for the St. Croix River at Calais, Maine. In 1861 and again in 1878 measurements were made at Lubec, Maine, for short periods of time. In 1887 and 1888, the Geodetic Survey observed the tides for short periods at a number of stations while they were performing the detailed hydrographic mapping of the area. One month of observations were made in 1918 at Eastport, Maine, and Midjik Bluff and St. Andrews, New Brunswick. The major station in the area is the permanent tide-gaging station which the U.S. Coast and Geodetic Survey has maintained at Eastport, Maine, since 1929. The instrument is the standard Coast and Geodetic automatic tide gage which has been used by the agency for many years. A local observer takes care of the station and periodically sends the instrument record to Washington, D. C., for processing. The processed data are tabulated as indicated below:

(1) On form 138 on which the time and stage of each high and low water is entered. One form covers one month of record.

(2) On form 362 on which the tide height at each hour is entered. One side of the form covers one week of record, and both sides of the form are used.

(3) On form 472 on which is entered the mean tide range for each month for a particular station. The mean range for each year is computed on this table.

Copies of all forms 138 which had been tabulated for Eastport were obtained for analysis for the proposed tidal power project. Data on the other observations were not obtained because the information was adequately covered in their yearly publication, "Tide Tables, East Coast, North and South America, including Greenland." The table entitled "Tidal Differences and Other Constants," gives differences in time and height for high and low tides for various locations compared with Eastport. Table 3-1, extracted from "Tide Tables" for 1958, provides information on stations in the project area for ready reference.

c. Cooper's Observations. Tidal observations were made by Dexter P. Cooper, Inc., at a number of locations in the Passamaquoddy Bay area in the period from 1924 to 1929. Cooper's studies of the tidal power were apparently based on long-term tide observations at Saint John, New Brunswick, about 50 miles northeast from Eastport, Maine, corrected by constants for each location. Records for short periods were also taken at Cummings Cove on Deer Island, Welshpool on Campobello Island, and at other places as noted on plate 3-3. Since continuous Eastport gage records were available for the current study of the international tidal power project, no use was made of these fragmentary records.

A particular problem was recognized at that time in the Falls Island area of Cobscook Bay where channel restriction caused a reversing falls. To examine this problem and the general problem of water slopes in the project pool areas, simultaneous staff readings of the tides were taken at several locations. These observations and studies based on them established the general scope of the pool-slope problem for the current tidal project and accordingly a detailed description of these studies is given later in this appendix. Cooper also took numerous staff gage records during the progress of his underwater mapping operations. The gage readings were used to reduce soundings so that the resulting maps are all referred to the mean sea level datum. These readings are not listed in this appendix.

d. U.S. Corps of Engineers Studies, 1935. The United States Corps of Engineers in their studies of a one-pool tidal power project located entirely in the United States made a comprehensive survey of tides in the Cobscook Bay area. Gage locations are shown on plate 3-3 and the types of records obtained are summarized below:

Type of gage	No. of locations	Length of record
Standard	4	4 to 6 mos.
Portable	13	1 month
Staff	13	4 to 20 days
Staff	2	1 month

Of the above records, only the rolls of the standard tide gages, and summaries (without time differences) of the gages are available. The lack of information on time of high and low tide with respect to the Eastport gage made it impossible to use the information on the summaries. The tide rolls in the Gravel Point indicate that the water surface in Dennys and Whiting Bays is essentially level.

e. U.S. Geological Survey, 1951. In the summer of 1951, the United States Corps of Engineers and the Geological Survey made experiments in the tidal project area to determine whether a modified sonic sounding device might be used to furnish information on the depth of underwater sediments. In connection with this work, automatic stage recorders were set up by the Geological Survey at Lubec, Maine (key number 17 on plate 3-3); Cummings Cove, Deer Island, New Brunswick (18); Letite, New Brunswick (20); and Chocolate Cove, Deer Island, New Brunswick (45). Information from these gages, supported by information from staff gages, were used to reduce all soundings to a mean sea level datum. These data indicated that the differences in amplitude and phase at the locations studied were quite small. The studies carried out in 1951 are described in more detail in appendix 1, "Underwater Mapping."

f. Tidal Project Survey, 1957 - 1958. Five automatic stage recording instruments were purchased in 1957 for the current survey. These were installed at Eastport, Maine, (key number 1 on plate 3-3); St. Andrews, New Brunswick (3); Letite, New Brunswick (20); Wilson Beach, Campobello Island, New Brunswick (40); and Fairhaven, Deer Island, New Brunswick (41). The gage at Eastport was installed to serve as a base for comparing other gages and to provide data for reducing soundings. The new gage also furnished the only Eastport tide gage record from July 1957 to 1 August 1958, during part of the period that the Coast and Geodetic automatic tide gage was out of service. The other gages were set at or near potential sites for the tidal project powerhouse or gates. It soon became apparent that the St. Andrews site would not be used for the tidal powerhouse (the St. Andrews plan, Study 6A - 2.613 was abandoned as described in appendix 5, "Selection of Plan of Development"). Accordingly, the gage was dismantled and used for a series of four 1-month observations in the Falls Island area. The data was planned for detailed studies of the effect of the constrictions in this area on power production. The gages were located at Edmunds (key number 16 on plate 3-3), Falls (42), Neck (43), and Denbow (44). The Passamaquoddy tidal power survey gaging program ended 1 August 1958.

3-05 ANALYSIS OF TIDE STAGE DATA

a. General. Analysis of the tide stage data described in previous paragraphs was generally limited to a compilation and evaluation of the observed data. A mathematical analysis of the astronomical tide producing forces, and the effects of shore and bottom configurations was not, in general, found necessary. These factors are described in great detail in a number of publications such as "Tidal Hydraulics," by Brig. Gen. George P. Pillsbury, USA, Retired; "The Tide," by H. A. Marmer; and "Manual of Harmonic Analysis and Predictions of Tides," Special Publication 98 of the U.S. Coast and Geodetic Survey. An exception to the above is the analysis described later in this appendix concerning an evaluation of the effect of the proposed international tidal power project on the tides in the Bay of Funday. In the evaluation studies, Eastport gage has been considered the basic gage because of its length of record. Other gages have been related to the Eastport gage.

b. Type of Tide. Tides at Eastport, Maine, closely approximate a sine curve in shape and have two well defined high tides and low tides each lunar day of 24 hours 50 minutes. One high tide during a day is usually higher than the other, and one low tide is lower than the other. Tide heights also change from day to day, affected to the greatest extent by the phases of the moon which completes a cycle in 29.5 solar days, and the distance of the moon from the earth which completes a cycle in 27.5 days. Greatest spring tides occur when the moon is nearest to the earth (perigee) and is either new or full. At new moon the earth, moon and sun are in line in that order. At full moon, the moon, earth, and sun are in line in that order. Neap tides at apogee (moon farthest from the earth) have the least range.

The nature of the tides is illustrated by figure 1 on plate 3-4 which shows the tides for a 29.5-day period, 2 October to 31 October 1937. Also indicated with the tide curves are data on the aspects of the moon having the greatest bearing on the tides. The month of October 1937 has been used for computations of tidal project power as described in appendix 13, "Project Power," and for other studies.

c. Means of Observed Tide Ranges. The tide range is defined for this appendix as the difference in level in feet between a low tide and the following high tide in feet. For a longer period of time, the mean tide range may be computed as the difference between mean high water and mean low water for that period. Tide range is of primary interest in the current study of the tidal power project, because, as developed in appendix 13, the energy output of the tidal power plant varies with the tide range. Accordingly, a series of studies concerning tide range were undertaken. In the first of these, monthly mean tide ranges at Eastport, Maine, were copied directly from the forms 138, obtained from the United States Coast and Geodetic Survey, for each month for the years 1930 (the first full year for which tide observations were available) through 1956. These are summarized in table 3-2. The lowest monthly mean range, 17.10 feet, occurred in December 1930, and the largest, 19.01 feet, in October 1940. Also shown in the same table are the annual mean tide ranges which vary from 17.52 feet in 1930 to 18.52 in 1940. The 19-year mean for the years 1930 through 1948 is 18.06 feet and the period 1938 - 1956 is 18.14 feet. The average of these two values is 18.10 feet. The 19-year period is used as being most nearly representative of a complete cycle of the factors causing tides. Also shown at the bottom of table 3-2 are 19-year means for each month. The average of the 19-year means for December, the month of maximum power demand, is 17.94 feet, 0.16 foot less than the mean tide range of 18.10 feet.

d. Trend of Tide Range.

(1) At Eastport, Maine. A tendency of the tide range at Eastport to increase is indicated by 19-year moving averages as follows:

19-year period	Mean range in feet
1930-48	18.06
1931-49	18.06
1932-50	18.07
1933-51	18.08
1934-52	18.09
1935-53	18.10
1936-54	18.12
1937-55	18.13
1938-56	18.14

The average rate of increase was 0.01 foot per year.

(2) At Saint John, New Brunswick. The tide gage records for Saint John have not been processed in the same manner as the Eastport records. However, the Saint John records have been harmonically analyzed by the Canadian Hydrographic Service since 1895, and these analyses give the amplitude (H) of the principal semi-diurnal constituent (M_2). The range of this constituent is very close to the mean range of the tide, and any change in the mean range would also be apparent in the constituent M_2. The increase in mean tide range at Saint John is indicated by the following means for periods of 18.61 years each:

Period	Mean range (2H of M_2 in feet)
1895-1913	19.58
1914-1931	19.71
1932-1950	19.85

The average rate of increase was 0.007 foot per year.

(3) Summary. The causes of the increase in tide range are not known. The astronomical forces causing the tides are believed to have varied but little in thousands of years. The indicated rate of increase of the tide range is between 0.007 and 0.01 foot per year. If the trend should continue, the increase in tide range in the next 100 years would be between 0.7 and 1.0 foot.

e. <u>Frequency of Tide Ranges, High and Low Waters.</u> The heights of each high and preceding low tide and date, from the U.S. Geological Survey forms 138 for the period 1931 through 1949, were entered on punch cards. A high-speed electronic computer was then used to compute the tide range and to punch it on the card. There were 13,400 cards used in this study, one for each tide range. Using electric accounting machines (a sorter, a collator, and a tabulator), the cards were sorted into groups according to the tide range. The cards in each group were counted, and the results were summed and plotted as the "all months" tide range occurrence curve shown on figure 2, plate 3-4. In the period (1931 through 1949) the mean tide range was 18.06 feet, the maximum was 25.7 feet, and the minimum 11.3 feet. The December tide range and the high and low tide elevation occurrence curves, shown on plate 3-4, were computed in a similar manner. The curves of tide range frequency, figure 2, were used in the tidal power studies; and the curves of high and low tide elevation frequency, figures 3 and 4, were used as guides in setting the levels of the various tidal project features such as tidal dams (top and bottom level of slope protection), locks, and filling and emptying gates.

3-06 PREDICTED EASTPORT TIDES

a. <u>General.</u> The United States Coast and Geodetic Survey predicts the time and level of each high and low tide for a number of stations by means of a mechanical analog computing machine located in their Washington, D. C. offices. These predictions are published annually in regional publications of "Tide Tables." Predictions for the Eastport station are in the volume subtitled "East Coast, North and South America, including Greenland." The ability to predict tides has an important bearing on the concept of a tidal power project, because this enables the prediction of power production to a degree of accuracy not attainable at any normal hydroelectric power project. In view of the foregoing, studies were undertaken to compare predicted tide ranges for Eastport, Maine, with the tide ranges which were observed at this station. Tide ranges are more significant than tide heights as far as power production is concerned.

b. Differences Between Predicted and Observed Tide Ranges. To evaluate the error inherent in predicting power production during any one tide cycle, each predicted tide range was compared with the corresponding observed range. The year 1940 was selected for the comparison because the mean predicted and observed tide ranges for the year are very nearly the same. The difference between each predicted tide range and each observed tide range was computed, and the differences were grouped according to size and sign. These data were plotted to produce the occurrence curve shown on plate 3-5. This curve is a measure of the day-to-day variations of the actual tide ranges from those predicted, and reflects such noncyclic influences as wind and barometric pressure. Any desired information regarding the distribution of the differences can be obtained from the curve. In a year when the predicted and observed mean ranges were nearly equal, 5 percent of the predicted tide ranges exceeded the observed by more than 0.97 foot and 5 percent of the predicted tide ranges were less than the observed by more than 0.88 foot.

c. Means of Predicted Tide Ranges. The "Tide Tables" previously cited were used to compute the monthly mean tide ranges. These are tabulated on table 3-3. The smallest monthly mean, 16.61 feet, was predicted for May 1952; and the largest, 19.13 feet, was predicted for October 1940. The annual means were also computed in the same manner as for the analysis of observed tide ranges. The smallest predicted annual mean is 17.08 feet for 1952 and the largest 18.56 feet for 1939. The comparable values for observed conditions (par. 3-05c) are 17.52 for 1930 and 18.52 for 1940.

d. Differences Between Predicted and Observed Monthly Mean Tide Ranges. Using the technique described in the preceding paragraph 3-06b and the data for the 19-year period 1930-48 from tables 3-2 and 3-3, the frequencies of various differences between predicted and observed monthly mean tide ranges were computed. The results yielded the curve on plate 3-6. This curve intersects the zero line at about 18 percent, indicating that 82 percent of the predicted monthly mean tide ranges were less than observed. Carrying the analysis still further, it would found that, on the average, predicted monthly mean tide ranges were 0.29 foot less than the observed. 5 percent of the predicted monthly mean tide ranges exceeded the observed by more than 0.26 foot. 5 percent of the predicted monthly mean tide ranges were less than the observed by more than 0.77 foot.

e. Differences Between Predicted and Observed Annual Mean Tide Ranges. Also shown on plate 3-6 are the differences between predicted and observed annual mean tide ranges for the same 19-year period, 1930-48. It can be seen that the trends are similar to those for the differences of monthly means of predicted and observed tide ranges. In view of the obvious and substantial differences between predicted and observed mean tide ranges, the annual mean ranges of both predicted and observed tides were plotted for each year as shown on plate 3-7. This showed that, for the years for which relatively high tides were predicted, the difference between the predicted and observed annual mean tide ranges was quite small; and conversely, that where small annual mean tide ranges were predicted, the observed mean range was substantially greater than the predicted. On plate 3-7 are plotted the differences between the observed and predicted annual mean tide ranges. The differences are cyclical, suggesting that a reevaluation of values used in predicting the tides might be made in the interests of accuracy. Since better tide predictions are not needed for navigation, the reevaluation can be justified only by the construction of the proposed tidal power project.

f. Computed Tide Curve. In computing the power which could be developed by the tidal power project, using the high-speed digital computer described in appendix 13, "Project Power," it was necessary to use a complete tide curve rather than the tide range only. This was necessary because, the routing of flow from the ocean through the filling gates to the upper pool, through the powerhouse to the lower pool, and through the emptying gates back to the ocean was made using 15-minute time intervals to secure the needed accuracy. Because of the nature of the computer, it was found desirable to use the tide equation rather than to read 15-minute observed tide stages. The United States Coast and Geodetic Survey furnished for this purpose the following data for computing Eastport predicted tides for the year 1937:

$h = Z_o + \sum fH \cos(at + \alpha)$, where
h is height of tide at any time "t"
Z_o is elevation of m.s.l. above chart datum.
f is an amplitude factor which varies throughout a cycle of 18.6 years.
H is average amplitude of a constituent.
a is angular speed of a constituent.
α is initial angle when $t = 0$.

If $Z_o = 0$ the formula will be $h = \sum fH \cos(at + \alpha)$ and the heights will be referred to m.s.l.

The constants for predicting tides at Eastport for 1937 are as follows:

Constituent	fH	a	α 0^h Jan 1
M_2	8.65	28.9841042	322
S_2	1.45	30.0000000	13
N_2	1.85	28.4397295	249
K_1	0.45	15.0410686	258
M_4	0.20	57.9682084	38
O_1	0.35	13.9430356	147
M_6	0.15	86.9523127	262
ν_2	0.40	28.5125831	357
μ_2	0.05	27.9682084	128
$(2N)_2$	0.25	27.8953548	176
λ_2	0.15	29.4556253	89
S_1	0.05	15.0000000	103
J_1	0.05	15.5854433	357
S_{sa}	0.05	0.0821373	191
Sa	0.05	0.0410686	133
Q_1	0.05	13.3986609	53
T_2	0.10	29.9589333	14
P_1	0.15	14.9589314	233
L_2	0.65	29.5284789	184
K_2	0.40	30.0821373	236
$(MS)_4$	0.05	58.9841042	61

a is in degrees/solar hour.
α is in degrees.
fH is in feet.
t = 0 at 0^h January 1
The time is eastern standard.
(time meridian 75°W)

Using the above relation, the computer produced, among other things, a tabulation of tide elevations at 15-minute intervals for a lunar month, 29.5 solar days, extending from 0 hours 2 October to 12 hours 31 October 1937. This period was selected for power computations because the predicted mean tide range approximated the long term observed mean tide range, and because the frequency distribution of the tide ranges approximated that for the long term. Because the computations were made only for 15-minute intervals, it was necessary to compute further to determine the levels of the high and low tides.

This was done by fitting a parabola to the three highest (or lowest) computed points at a high (or low) tide, setting the first derivative equal to zero, and computing the height for this point. This resulted in the formula:

$$Ym = Y_2 - \frac{(Y_1 - Y_3)^2}{8(Y_1 - 2Y_2 + Y_3)}$$

where Ym is the high (or low water) elevation,

Y_2 is the maximum (or minimum)

tabulated elevation,

Y_1 is the preceding tabulated elevation,

Y_3 is the following tabulated elevation.

The high and low tides in the period under consideration were computed using the above relation, and the rising tide range computed. The mean of these 57 tide ranges is 18.12 feet, which is satisfactorily close to the mean range of observed tides at Eastport, Maine, 18.10 feet (par. 3-05c). The high and low tides are shown on figure 1, plate 3-4.

g. Adjustment for the Longitude of the Moon's Node. The inclination of the moon's orbit to the equator has a maximum value of 28.6° and a minimum value of 18.3°. The time between the maximum and the minimum is 9.3 years, making the cycle 18.6 years long. The maximum inclination occurs when the ascending node the moon's celestial orbit and the ecliptic coincides with the vernal equinox. The minimum inclination occurs when the coincidence is with the autumnal equinox. This long-term variation of the moon is the basis for the use of the 19-year period for determining the mean tide range. The long-term mean tide range can be approximated by multiplying a 1-year mean by a factor determined from a consideration of the longitude of the moon's node and other factors. A tabulation of factors of this sort is given on page 92, "Tidal Datum Planes," by H. A. Marmer, Special Publication No. 135, Revised (1951) Edition, United States Coast and Geodetic Survey. Knowing the mean tide range at Eastport, Maine, it appeared that the annual mean tide range for any year might be approximated by dividing by the published factor for the year. Using the

18.10-foot mean of the observed tide ranges, the sinusoidal line, shown on plate 3-7, was developed. It appears that the prediction on this basis is nearer to the observed annual means than the annual means computed from published predictions. Therefore, an accurate prediction of tidal energy output for any year can be made insofar as tide ranges affect it.

3-07 ANALYSIS OF 1957-58 TIDE OBSERVATIONS

a. General. Described below is the analysis of the tide observations made in 1957-58 in connection with the study of the proposed international tidal power project, and described in par. 3-04f.

b. Procedure. The automatic tide gages installed at Letite, Wilson Beach, and St. Andrews, N. B., and Eastport, Me., were checked daily by the observers. Record rolls were collected during periodic visits of survey personnel when the installations were inspected and repaired. The tide gage rolls were processed to determine the time and stage of each high and low water. These values were then tabulated on a printed form. A sample tabulation is presented as table 3-4.

c. Graphical Representation. The heights of high and low water were plotted against time, and compared with the predicted Eastport tides. This graphical comparison is shown on plates 3-8 through 3-24. Also entered on these sheets are the wind velocity, and direction, and the barometric pressure in inches of mercury, which data were secured from the United States Weather Bureau observer in Eastport, Maine.

d. Comparison with Eastport Gage. The tide data obtained from the other automatic gages were compared with the Eastport gage with respect to time and height of high and low tides, range, and half-tide level, and the average differences computed for each month. These monthly average differences are shown on table 3-5 and a summary for the period of record is given below:

	Letite N.B.	Wilson Beach N.B.	Fair-haven N.B.	St. Andrews N.B.
Time difference, minutes				
High water	0	+2	+5	+6
Low water	-3	-9	+5	+8
Height difference, feet				
High water	+0.01	-0.11	+0.05	+0.30
Low water	+0.17	+0.13	-0.31	-0.56
Range difference, feet	-0.16	-0.25	+0.37	+0.86
Half-tide level difference, feet	+0.09	+0.01	-0.13	-0.13

Minus signs indicate times earlier than Eastport and lower levels and lesser ranges than Eastport. The foregoing table is significant to operation of the proposed international Passamaquoddy tidal power project because the low tides at the emptying gates, judged from the Wilson Beach record, might be 0.13 foot higher than at Eastport. The lower pool emptying would not therefore be as complete by that small amount as indicated by computations based on the Eastport gage. Filling of the upper pool would be about as indicated by computations using the Eastport gage because high water at Letite, where 40 of the filling gates would be located, has very nearly the same tides as Eastport, and because the remaining filling gates are at Deer Island Point, very close to the Eastport reference gage. In view of the foregoing, use of the Eastport gage records as a basis for computing tidal project power is considered permissible.

3-08 EFFECT OF STORMS ON TIDES

a. General. The previous discussion on comparison of individual observed and predicted tide ranges has, to some extent, pointed up the effects of storms on tide ranges. This is based on the assumption that the principal difference between an observed and predicted tide range would result from meterological effects not accounted for in the tide equation. The analysis was statistical in that it included relatively long periods of time in which many tide cycles occurred and no effort was made to modify predicted tide ranges for winds or barometric pressure gradients.

On a long-term basis, the tide ranges, and hence the tidal plant power, can be predicted with good accuracy. (A comparison of tide ranges is discussed in par. 3-06 this appendix, and the predictability of tidal power is discussed in appendix 13). No attempt has been made to correlate winds and barometric pressure with tide range. This problem would be of principal importance in the day-to-day operation of the tidal plant and therefore should be examined in detail if the project is authorized for construction. However, a limited discussion on observed effects of wind and barometric pressure on Eastport tides is given in the next paragraph.

b. Effect of Winds on Tides at Eastport. Wind records are available for Eastport, Maine, from 1885 until 1952, when the Eastport Weather Bureau office closed. Of this period, tide records are available since 1930. Observed and predicted tide ranges were compared for 3-day periods, centered on the days when maximum wind velocity was observed. The maximum wind effect occurred on 20 November 1945. A maximum (5-minute) wind velocity of 55 miles per hour from the east was recorded. The afternoon low tide was 2.3 feet higher than predicted, and the following high tide was 0.6 foot lower than predicted. Thus, the observed tide range was 2.9 feet less than predicted.

On 8 January 1958, a 30-mile an hour wind for 6 hours from the southeast (barometer reading of 28.5 inches of mercury) raised a low tide about 4 feet but high tide only 1 foot. On 16 through 18 January winds up to 22 miles an hour and a barometric reading of 29.0 inches raised low tides up to 1 foot and high tides up to about 2.5 feet. These occurrences are shown on plate 3-18.

Hurricane "Edna" passed over Eastport in September 1954. Low tide was raised about 1.4 feet and high tide by 2.2 feet.

It appears that storms generally increase both high and low tide levels. Tide range may be either increased or decreased.

3-09 SLOPES IN TIDAL PROJECT POOLS

a. General. Slopes in the pools of the tidal power project would affect the power output of the tidal project. Pool slopes would be the greatest during the periods when the pool levels are changing most rapidly. These periods are when the upper pool of the selected two-pool project is being filled by the gates at Letite

Passage and Deer Island Point and when the lower pool is being emptied by the gates at Pope Island. Comparison of the Eastport, Maine, and Letite, New Brunswick, gages with that at St. Andrews, New Brunswick, indicated that slopes in the upper pool would be negligible. The water surface near Falls Island in the Cobscook Bay area of the lower pool was found by Cooper to have a considerable slope which would influence power output.

b. Cooper's Studies. In December 1927, Dexter P. Cooper had a series of simultaneous gage readings taken during a spring tide in the lower pool area (Cobscook Bay) in order to evaluate the effect of slopes on power production. Plate 3-25 indicates the locations of these observations, and shows them plotted against time. Instantaneous differences of as much as 7 feet were observed within the pool area. A detail map and a table of flow areas, on this plate, indicate the locations where most of the water surface slope occurs. (Also shown on plate 3-25 are observations made in July 1929 during a neap tide in the same area. Tide differences were about 3 feet.) Using the 1927 observations, studies dated July 1928 were made assuming Cobscook Bay emptied by thirty-five 30-by 30-foot venturi gates. Apparently a plan with alternate discharge to the ocean was being studied since no inflow to the lower pool was indicated, that flow being discharged directly to the ocean during the limited period of the tidal cycle being studied. The starting elevations of the lower pool and the ocean for the study were 4.0 feet, and ocean low tide was -9.4 feet. Final elevation of the lower pool, about 1.5 hours after gate closure, was -7.7 feet. Assuming the lower pool level, the final low pool elevation was -8.8 feet. The difference, 1.1 feet, was the loss attributable to pool slope. Instantaneous profiles in Cooper's files indicated that nearly all of the water level drop was in the Falls Island area. In view of the large effect of the constriction, Cooper made a study of an improvement at the constriction involving a channel 600 feet wide and 3000 feet long with the bottom at el. -45. Using this channel, and assuming an average tide, routing was carried out for the pool emptying cycle, assuming it to start at el. 11.0. With no inflow to the lower pool, 46 emptying gates, and all of the pool slope concentrated in the Falls Island area, a maximum difference in water level over the length of the improvement was found to be 0.4 foot, and negligible at the time of gate closure.

c. <u>Analysis Made in 1958</u>. Studies were undertaken to determine the effect of the constriction in the Falls Island area on the power which could be developed by the currently proposed tidal power project, and to determine whether channel improvements would be justified. The currently proposed tidal power project would have a considerably larger lower pool area than considered by Cooper. This factor tends to reduce the adverse effect of the Falls Island constriction. The analysis as it directly pertains to power is made in appendix 13, "Project Power." The analysis which follows pertains to reducing tidal observations to hydraulic equations to facilitate the studies of the effect on power. The equation sought was for the discharge through the opening connecting Cobscook Bay with Dennys and Whiting Bays. The usual equation for a contracted opening is

$$Q = Ca \sqrt{2gh}$$

Where Q is the discharge, C is a coefficient, a is the area of the minimum cross section, g is the acceleration of gravity, and h is the difference in water levels. In this case, the area was not known, and 2g was a constant, so the equation was simplified to the form of Q = c h where Q is the rate of flow in c.f.s., C is a factor which includes the area of the channel, acceleration of gravity and the discharge coefficient, and h is the level of Cobscook Bay minus that of Dennys and Whiting Bays. When Dennys and Whiting Bays are higher than Cobscook Bay, different conditions could prevail, so a separate analysis was made for this reverse flow condition.

The elevation for Cobscook Bay was assumed to be the same as that for East Bay. On the basis of data in the 1958 "Tide Tables," U.S. Coast and Geodetic Survey, tide curves for East Bay were developed from the observed marigram of the Eastport gage. A time difference of 15 minutes and a ratio of ranges of 19.1 to 18.2 feet were used. Simultaneous tide curves were plotted for two cycles of neap tides and two cycles of spring tides. The first cycle is shown on plate 3-26, (figures 1 and 2). Scaled from these curves were the heads as previously described. These were plotted as head curves as shown on figures 1 and 2, plate 3-26. The discharge curves shown on these figures were estimated by noting the stage in Dennys and Whiting Bays at numerous times during the tide cycle. The volume of water in storage corresponding to these stages was then determined from the curve shown on figure 5, plate 3-26. The change in volume in cubic feet, divided by the time interval in seconds, yielded the average discharge during the time interval. This value was plotted at the mid-point of the time interval under consideration. Connecting the points yielded the cited discharge curve. Values of "Q" and "h" were read from these two curves at 15 minute intervals, omitting periods when acceleration was large, from which values for "C" were computed. The values for "C" were plotted for different water heights of the bay into which the water was flowing for the two flow directions under consideration. The results are shown on figures 3 and 4, plate 3-26.

3-10 CHANGES IN SEA LEVEL

a. General. Mean sea level at any place is determined by averaging observed hourly tide heights over an extended period of time. Mean tide level or half-tide level is the mean of the high and low tide elevations. It would be the same as mean sea level if the tide curve was purely sinusoidal. Over a period of a year or more the difference between mean tide level and mean sea level at a given location is nearly constant.

b. Trend of Sea Level. A gradual rise in sea level has been noted throughout the world. Special publication No. 135, "Tidal Datum Planes," U.S. Coast and Geodetic Survey, gives data on changes in sea level along the coasts of North America. Plate 3-27 is copied from that publication and illustrates the trend along the Atlantic Coast. Added to the plate are points representing annual mean tide level for the Eastport gage. These points show a trend similar to that of the rest of the Atlantic Coast. Sea level appears to have been rising at an accelerated rate since 1930. The rate of rise of half-tide elevation at Eastport was about 0.76 foot per century computed on the basis of the 10-year means, 1930-39 and 1940-49.

c. Probable Future Changes in Sea Level. This matter was referred to the Committee on Tidal Hydraulics, U.S. Corps of Engineers, Department of the Army, and their answer is summarized as follows:

Numerous hypotheses have been proposed by earth scientists in explanation of the rise in sea level, but none has been validated nor supported by physical data to an extent which would permit an accurate prediction of the sea level change during the next century. During the short period of record for which accurate tidal data are available on the North American continent, the rate of sea level rise is indicated to be accelerating. While the data are insufficient to justify statistical analysis, the following assumptions are believed to be appropriate for planning purposes:

(1) During the next 50 years mean sea level will probably rise not less than 0.5 foot nor more than 1.5 feet above the present (1948-58) mean.

(2) Over a 100-year period the extent of rise is unlikely to be less than 1 foot and may be as much as 3 feet.

3-11 EFFECT OF THE TIDAL PROJECT ON TIDES

a. General. A comparison of the average tide ranges (plate 3-1) of shore areas open to the ocean with those at the head of the Bay of Fundy, which are as high as 41.6 feet, indicates that the tides are strongly influenced by the resonance of the Gulf of Maine - Bay of Fundy system. Construction of the proposed tidal power project would change this system by changing the timing and amount of flow into and out of Passamaquoddy and Cobscook Bays. Such a change could conceivably change the tides in the Bay of Fundy, and at the tidal project itself, thus affecting the amount of power it could generate.

b. Effect on Regional Tides. A study of the effect of the proposed tidal project on Bay of Fundy tides was undertaken by Arthur T. Ippen and Donald R. F. Harleman, Consulting Engineers, Massachusetts Institute of Technology, Cambridge, Massachusetts. The report on their studies (unpublished) indicates that the tidal system in the Bay of Fundy is not highly resonant. The Bay of Fundy, closed at one end and open to the ocean at the other end, forms a damped co-oscillating system. The phase change of this system was found to be 68 degrees and the amplification of tides 2.5 times, while a phase shift of 90 degrees and infinite amplitudes at the head of the basin would represent perfect resonance. The system with a 68-degree phase shift was found relatively insensitive to disturbances. The tidal project would change peak lateral flow from 1.25 percent of the longitudinal Bay of Fundy flow to 0.70 percent for inflow and 0.45 percent for outflow. The change would be a decrease in the system loading and thus would operate toward slightly increasing tide ranges. It is doubtful that any changes at all could be detected in view of the small size of the flow modifications.

c. Effect on Local Tides. Narragansett Bay located on the coast of Rhode Island is a bay system 30 miles long in the north-south direction and 15 miles in an east-west direction, and having a total area of about 450 square miles. Hurricanes of recent years have induced wind-driven tides which have caused loss of life and property in the cities and towns adjoining the bay. The Corps of Engineers, U.S. Army, has made extensive studies, including hydraulic model experiments, of providing protection from these hurricane tides. The plans of protection tested in the model included barriers placed across the bay at various locations. The mean tide range in the bay is about 4.1 feet, and the hurricane tides have reached as high as 18 feet above mean low water. The barriers had no significant effect on normal tides, but a build-up of about half a foot on the hurricane tide was observed at the model barrier if it was located near the bay entrance. The build-up was nearly 2 feet when the model barrier was about halfway up the bay; the build-up decreased as the barrier was placed farther up the bay, reaching zero with the barrier at the head of the bay.

The foregoing suggests that similar effects might be expected at the tidal power project barriers. The question is considered to be one more local in nature than that analysed by Drs. Ippen and Harleman in the studies referred to in the previous paragraph. The barriers could presumably lower the low tide level as well. The combined effect would be to increase tide range which, in turn, would increase power production of the tidal project. Repeated examination of the problem, however, has failed to develop a method of computation which would prove conclusively the existence of this effect. For this reason, the procedure adopted early during the survey of computing power on the basis of the Eastport gage has been retained. If the tidal power project is authorized for construction, this factor should be examined by testing the entire project with a hydraulic model.

3-12 OBSERVATION OF TIDAL CURRENTS.

a. General. Because of the extreme tides in the project area, strong tidal currents prevail particularly in the more restricted passages. One of these is the Falls Island area already described. There, however, velocities, per se, do not influence the tidal project; it is the head losses which would reduce the energy which might be developed. Existing velocities do influence the construction of the project, but the most critical velocities would be those which would prevail after a considerable portion of the project is completed, and which would be quite different from those prevailing under natural conditions. These can only be evaluated by hydraulic computations or model studies. Velocities prevailing under existing conditions are of less significance, and consequently only limited observations have been made.

b. U. S. Coast & Geodetic Survey Observations. The U.S. Coast and Geodetic Survey has made a few current observations at the site of the proposed development at the locations indicated on plate 3-28.

c. Cooper's Observations. In 1927 Dexter P. Cooper, Inc., made current observations in the channel between Race Point and Ruth Point in order to estimate the division of flow around Falls Island. The location is indicated on plate 3-28.

d. 1935 Observations. In 1935 the U.S. Corps of Engineers made current observations along the centerlines of dams being considered at that time from Estes Head to Treat Island, Treat Island to Dudley Island, and Dudley Island to Lubec.

e. Recent Observations for the Survey. In February of 1957 velocity measurements were made by the Eastport field office at 8 sites, in the vicinity of the proposed dams, as shown on plate 3-28. The observations were made for use in connection with the design and anchorage of the deep water drilling equipment. Two current velocity meters were used to make continuous measurement for varying depths at each site. For each site the results were plotted graphically together with the vertical velocity profiles and the curve of the predicted tide at Eastport, Maine. The field notes indicate considerable turbulence in the tidal currents, however the plotted graphs show the magnitude of the velocity to be fairly uniform from surface to bottom. Data pertaining to these velocity measurements are summarized in table 3-6.

f. Recent Observations by Canada. In 1957 the Bureau of Fisheries made current observations at 16 locations at the project site. The locations are shown on plate 3-28. A copy of the data is in the files of the Survey.

3-13 SUMMARY.

The studies described in the previous paragraphs are summarized as follows:

a. Observed tide ranges at Eastport averaged 18.10 feet and vary from 11.3 feet to 25.7 feet.

b. Observed monthly mean tide ranges show less variation, the smallest being 17.10 feet, and the largest 19.01 feet.

c. Observed annual mean tide ranges show still less variation, the smallest being 17.52 feet and the largest 18.52 feet.

d. Observed 19-year mean tide ranges vary from 18.06 feet to 18.14 feet.

e. Individual tide ranges vary considerably from predicted values. In a year when the predicted and observed mean ranges were nearly equal, 5 percent of the observed tide ranges were less than the predicted by more than 0.97 foot; and 5 percent of the observed tide ranges exceeded the predicted by more than 0.88 foot. These variations are principally the result of noncyclical factors such as wind and barometric pressure.

f. Observed monthly mean tide ranges average about 0.3 foot greater than the predicted.

g. Observed monthly mean tide ranges agree with predicted monthly mean tide ranges somewhat more closely than individual observed and predicted tide ranges.

h. Agreement between predicted mean annual tide range and the observed is close for years for which a large mean annual range is predicted. For years when a small mean annual range is predicted, the observed is usually greater than the mean predicted tide range.

i. Annual mean tide ranges can be predicted accurately for many years ahead from the mean observed tide range and published factors depending on the longitude of the moon's node.

j. Both high and low tide levels tend to be raised by winds, but no systematic correlation was found with the wind observed at Eastport.

k. The most striking effect of wind occurred on 8 January 1958, when the wind from the southeast averaging 30 miles an hour for 6 hours raised low tide by 4 feet and high tide by only 1 foot. At another time the wind raised high tide more than low tide.

l. The tides at the filling and emptying gate locations are very nearly the same as at Eastport, and consequently no correction to the Eastport gage records is needed in computing project power.

m. Significant slopes would occur in the tidal project pools only in the Falls Island area of Cobscook Bay in the lower pool. Coefficients were computed which permit computation of the effect on power production.

n. A gradual rise in the level of the ocean appears to be taking place. The rate appears to be too slow to affect the design elevation of the tidal project components.

o. The tidal project would tend to slightly increase local tide ranges, but the amount of this change would probably be so small that it could not be detected.

p. The tidal project might increase the tide levels at the barriers. Since this has not been proved conclusively, no allowance has been made in the tides used in computing project power.

q. Tidal velocities now prevailing in the project area have been measured at 8 locations. More critical velocities will, however, prevail during project construction.

APPENDIX 3

TABLES

TABLE 3-1

TIDAL DIFFERENCES AND OTHER CONSTANTS

(Data from "Tide Tables, East Coast of North and South America, 1958" by U. S. Coast and Geodetic Survey)

Key 1/ No.	PLACE	POSITION Lat. Deg.	Lat. Min.	Long. Deg.	Long. Min.	DIFFERENCES Time High Water Hr.	High Water Min.	Low Water Hr.	Low Water Min.	Height 2/ High Water feet	Low Water feet	RANGES Mean feet	Spring feet	Mean Tide Level 2/ feet
	NEW BRUNSWICK, BAY OF FUNDY	N.		W.		on EASTPORT Time meridian, 75° W.								
19	Welshpool, Campobello Island	44	53	66	57	-0	01[a]	-0	04[a]	+0.1	0.0	18.3	21.2	9.1
3	St. Andrews, Passamaquoddy Bay	45	04	67	03	+0	08[a]	+0	04[a]	+1.0	0.0	19.2	21.9	9.6
2	Midjik Bluff, Passamaquoddy Bay	45	07	66	54	+0	12[a]	+0	07[a]	+1.1	0.0	19.3	22.0	9.6
	MAINE													
1	Eastport	44	54	66	59	Daily predictions						18.2	20.7	9.1
5	Gleason Cove, Western Passage	44	58	67	03	+0	08	+0	07	+0.2	0.0	18.4	20.9	9.2
	St. Croix River													
6	Robbinston	45	05	67	06	+0	09	+0	09	+1.0	0.0	19.2	21.8	9.6
7	St. Croix Island	45	08	67	08	+0	10	+0	12	+1.4	0.0	19.6	22.3	9.8
8	The Ledge, New Brunswick	45	10	67	12	+0	17[a]	+0	20[a]	+1.8	0.0	20.0	22.8	10.0
9	Calais	45	11	67	17	+0	31	+0	34	+1.8	0.0	20.0	22.8	10.0
	Cobscook Bay													
10	Deep Cove, Moose Island	44	54	67	01	+0	08	+0	09	+0.5	0.0	18.7	21.3	9.3
11	East Bay	44	56	67	07	+0	14	+0	16	+0.9	0.0	19.1	21.8	9.5
14	Coffin Point	44	52	67	07	+0	33	+0	38	+0.1	0.0	18.3	20.8	9.1
16	Birch Islands	44	52	67	09	+1	05	+1	17	-0.6	0.0	17.6	20.0	8.8
12	Horan Head, South Bay	44	52	67	04	+0	18	+0	21	+1.0	0.0	19.2	21.9	9.6
17	Lubec	44	52	66	59	-0	03	-0	01	-0.7	0.0	17.5	20.0	8.7
	West Quoddy	44	49	66	59	-0	09	-0	15	-2.5	0.0	15.7	17.9	7.8

1/ Key numbers refer to locations shown on plate 3-3.
2/ Heights are referred to mean low water, the datum of soundings on Coast and Geodetic Survey charts.
a For 60° W. meridian time add one hour to the predictions obtained using these differences.

TABLE 3-2

MEAN OBSERVED TIDE RANGE AT EASTPORT, MAINE

(Observed monthly, annual, and 19-year mean tide ranges, in feet, from records of the U.S. Coast and Geodetic Survey)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1930	17.30	17.37	17.60	17.67	17.69	17.77	18.05	17.79	17.49	17.22	17.16	17.10	17.52
1931	17.41	17.56	18.04	18.30	18.20	17.79	17.78	17.73	17.45	17.30	17.28	17.42	17.69
1932	17.56	17.48	17.65	17.81	17.67	17.47	17.39	17.59	18.22	18.24	17.79	17.81	17.72
1933	17.35	17.78	17.52	17.68	17.60	17.87	17.96	18.18	18.23	18.16	17.60	17.33	17.77
1934	17.29	17.36	17.85	17.86	18.05	18.07	18.22	17.77	17.60	17.17	17.34	17.12	17.64
1935	17.48	17.90	17.91	18.22	18.15	17.89	17.91	17.92	17.86	17.72	17.70	17.95	17.88
1936	17.95	18.09	17.97	18.04	17.90	17.92	17.87	18.11	18.66	18.95	18.28	18.32	18.17
1937	17.94	18.07	18.16	18.07	18.03	18.20	18.41	18.37	18.44	18.37	18.05	17.90	18.17
1938	17.94	18.09	18.25	18.31	18.50	18.55	18.80	18.42	18.28	17.91	17.91	17.95	18.24
1939	18.07	18.50	18.43	18.55	18.59	18.50	18.36	18.33	18.32	18.23	18.19	18.67	18.39
1940	18.60	18.70	18.48*	18.41*	18.10*	18.42	18.30	18.46	18.95	19.01	18.50	18.38	18.52
1941	18.28	18.32	18.28	18.18	18.21	18.47	18.74	18.63	18.48	18.39	18.15	17.97	18.34
1942	17.95	18.07	18.63	18.47	18.83	18.61	18.86	18.60	18.47	17.96	17.98	18.03	18.37
1943	18.26	18.63	18.67	18.71	18.67	18.47	18.35	18.35	18.44	18.40	18.30	18.19	18.45
1944	18.45	18.30	18.29	18.25	17.92	17.99	18.07	18.26	18.68	18.73	18.42	18.47	18.32
1945	18.22	18.16	18.23	17.91	18.07	18.12	18.55	18.20	17.67	17.96	17.58	18.07	18.06
1946	17.82	17.87	18.10	18.18	18.58	18.35	18.33	18.24	17.89	17.52	17.52	17.61	18.00
1947	17.89	18.18	18.22	18.11	18.16	18.03	17.86	17.76	17.87	17.78	17.83	18.00	17.97
1948	18.19	18.13	17.97	17.62	17.51	17.73	17.70	17.85	18.04	18.08	17.74	17.48	17.84
1949	17.51	17.38	17.65	17.66	17.60	17.80	18.01	17.92	17.81	17.48	17.53	17.22	17.63
1950	17.15	17.35	17.64	18.15	18.31	17.96	18.03	18.01	18.10	17.69	17.56	17.64	17.80
1951	17.85	18.08	18.05	18.08	18.07	18.02	17.69	17.65	17.71	17.91	17.66	18.07	17.90
1952	18.21	17.94	18.22	17.93	17.60	17.92	17.86	17.80	18.03	18.02	17.93	17.69	17.93
1953	17.67	17.76	17.88	18.03	18.02	18.11	18.38	18.21	18.42	17.99	17.98	17.70	18.00
1954	17.52	17.91	17.86	18.27	18.51	18.29	18.25	18.03	18.52	18.14	18.08	18.28	18.14
1955	18.27	18.49	18.18	18.60	18.32	18.35	18.12	18.23	18.28	18.38	18.34	18.64	18.35
1956	18.81	18.37	18.39	18.26	17.97	18.27	18.51	18.56	18.49	18.60	18.30	18.10	18.39
19-year means:													
1930-48	17.89	18.03	18.12	18.12	18.13	18.12	18.18	18.13	18.16	18.06	17.86	17.88	18.06
1938-56	18.03	18.12	18.18	18.19	18.19	18.21	18.25	18.18	18.23	18.11	17.97	18.01	18.14
Average	17.96	18.08	18.15	18.16	18.16	18.16	18.22	18.16	18.20	18.08	17.92	17.94	18.10

* Record incomplete - predicted tides used.

TABLE 3-3

MEAN RANGE OF PREDICTED TIDES AT EASTPORT, MAINE

(Mean tide ranges, in feet, computed from published tide predictions of the U.S. Coast and Geodetic Survey)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1930	17.07	17.12	17.26	17.17	17.24	17.30	17.55	17.36	17.15	16.88	16.93	16.86	17.16
1931	16.92	17.19	17.22	17.50	17.45	17.00	16.94	17.07	16.99	17.03	17.01	17.09	17.12
1932	17.23	17.38	17.14	17.22	17.03	16.84	16.68	17.05	17.34	17.39	17.42	17.26	17.17
1933	17.26	17.18	17.09	17.03	16.99	17.28	17.32	17.26	17.40	17.48	17.32	17.13	17.23
1934	17.09	17.23	17.24	17.23	17.32	17.42	17.67	17.46	17.15	16.83	16.95	16.98	17.21
1935	17.30	17.62	17.67	17.74	17.64	17.25	17.24	17.48	17.48	17.36	17.31	17.44	17.46
1936	17.67	17.68	17.57	17.52	17.26	17.18	17.05	17.54	17.86	18.05	17.76	17.71	17.57
1937	17.77	17.75	17.72	17.77	17.76	18.02	18.11	18.01	17.99	18.02	17.93	17.78	17.89
1938	18.01	17.99	18.07	18.29	18.39	18.46	18.66	18.58	18.08	17.81	17.76	18.08	18.18
1939	18.45	18.77	18.67	18.74	18.68	18.43	18.35	18.46	18.53	18.47	18.47	18.64	18.56
1940	18.74	18.70	18.48	18.41	18.10	18.12	18.05	18.40	18.79	19.13	18.89	18.56	18.54
1941	18.36	18.37	18.42	18.40	18.35	18.51	18.65	18.62	18.61	18.62	18.55	18.30	18.48
1942	18.30	18.36	18.49	18.71	18.99	18.76	18.61	18.61	18.37	18.12	18.33	18.39	18.50
1943	18.43	18.59	18.43	18.49	18.48	18.29	18.17	18.26	18.35	18.39	18.36	18.54	18.40
1944	18.13	18.10	17.87	17.68	17.45	17.51	17.46	17.76	18.11	18.52	18.17	17.95	17.89
1945	17.50	17.58	17.70	17.71	17.57	17.71	18.01	17.91	17.80	17.80	17.77	17.48	17.71
1946	17.18	17.35	17.50	17.79	18.06	17.72	17.69	17.58	17.44	17.32	17.31	17.34	17.52
1947	17.48	17.50	17.45	17.55	17.55	17.39	17.52	17.57	17.67	17.76	17.67	17.75	17.57
1948	17.80	17.71	17.61	17.30	17.35	17.46	17.26	17.04	17.48	17.72	17.37	17.15	17.44
1949	16.93	17.07	17.15	17.11	16.91	17.02	17.37	17.35	17.23	17.06	17.03	16.74	17.08
1950	16.68	16.97	17.10	17.43	17.64	17.23	17.16	17.16	17.02	16.81	16.88	17.01	17.09
1951	17.39	17.50	17.33	17.36	17.35	17.20	16.96	17.09	17.28	17.46	17.31	17.77	17.33
1952	17.50	17.25	17.07	16.78	16.61	16.84	16.92	17.06	17.32	17.52	17.19	16.95	17.08
1953	17.15	17.30	17.38	17.28	17.16	17.26	17.68	17.64	17.43	17.20	17.12	16.90	17.29
1954	17.12	17.56	17.54	17.86	17.99	17.62	17.60	17.56	17.50	17.34	17.38	17.51	17.55
1955	17.98	18.04	17.90	17.85	17.83	17.73	17.43	17.59	17.70	18.03	17.98	18.20	17.86
1956	18.38	18.02	17.91	17.65	17.51	17.77	17.85	17.99	18.15	18.25	18.05	17.84	17.96

TABLE 3-4

TIME AND HEIGHT OF HIGH AND LOW WATER

Eastport tide gage

Month March Year 1957 Time 75° W (e.s.t.) Datum mean sea level 1929

Gage Location Beardseleys Wharf, Eastport, Maine, U.S.A.

Controlling B.M. Todd (1957) El. 44.218 ft. m.s.l. Zero of reference gage - 11.70 ft. m.s.l.

DAY	HIGH		LOW		DAY	HIGH		LOW		DAY	HIGH		LOW		DAY	HIGH		LOW	
	time	ft.	time	ft.		time	ft.	time	ft.		time	ft.	time	ft.		time	ft.	time	ft.
1	10:41	10.1	4:31	-8.3	9	03:30	9.9	10:05	-6.7	17	11:32	12.3	05:33	-12.1	25	06:21	7.3	00:10	-6.9
	23:08	9.3	17:07	-7.6		16:08	8.9	22:35	-6.0		-	-	18:00	-11.9		19:03	7.1	12:48	-7.4
2	11:20	9.4	5:19	-8.2	10	04:29	9.5	11:07	-7.2	18	00:03	12.5	06:27	-12.1	26	07:23	7.5	01:23	-6.8
	23:42	9.7	17:41	-9.2		17:11	8.2	23:33	-7.2		12:35	11.6	18:47	-11.3		20:00	7.4	13:53	-7.5
3	11:50	10.0	6:00	-8.5	11	05:38	8.9	12:06	-8.2	19	00:58	11.8	07:10	-11.5	27	08:21	2.8	02:27	-7.3
	-	-	18:20	-9.1		18:23	8.5	-	-		13:13	10.4	19:25	-10.3		20:39	7.7	14:50	-7.7
4	00:05	9.4	06:37	-9.5	12	06:53	10.0	00:37	-7.4	20	01:27	11.0	07:56	-10.2	28	08:51	8.3	03:00	-7.9
	12:31	9.0	18:48	-9.3		19:24	9.6	13:10	-8.6		13:50	10.1	20:18	-8.2		21:17	8.4	15:15	-8.4
5	00:43	9.0	07:05	-9.1	13	07:52	10.8	01:39	-8.8	21	02:13	10.8	08:49	-8.8	29	09:35	9.1	03:31	-8.1
	12:54	8.0	19:11	-9.4		20:18	10.4	14:16	-10.1		14:43	8.7	21:09	-8.3		21:55	9.2	15:48	-8.5
6	01:19	8.5	07:38	-8.8	14	08:45	11.3	02:46	-10.5	22	03:11	9.2	09:40	-8.3	30	10:17	9.3	04:14	-8.9
	13:44	8.1	19:48	-8.6		21:11	11.1	15:14	-11.5		15:40	8.3	22:00	-7.2		22:23	9.5	16:27	-8.8
7	01:54	8.9	08:15	-8.7	15	09:41	11.8	03:54	-11.6	23	04:12	8.8	10:35	-7.6	31	10:43	9.2	04:46	-9.4
	14:24	7.9	20:32	-8.2		22:09	11.9	16:16	-12.1		16:44	7.5	22:55	-6.7		22:53	9.8	17:04	-9.4
8	02:35	8.6	09:00	-8.1	16	10:32	12.4	04:38	-12.0	24	05:17	8.1	11:43	-7.1	1				
	15:07	7.9	21:26	-6.9		23:03	12.8	17:04	-11.9		17:45	7.1	-	-					

Tabulated by J.F.C. Date 6/12/57 Checked by E.A.W. Date 7/24/57

TABLE 3-5

TIDAL DIFFERENCES
(Compared with Eastport Gage)

Datum - Mean sea level of 1929

Place and Month	Time in minutes High Water	Time in minutes Low Water	Height in feet High Water	Height in feet Low Water	Range in feet	Half-tide level in feet
Letite, N. B.						
March 1957	-3	-5	+0.12	+0.18	-0.06	+0.15
April	-1	-5	- .02	+ .12	- .14	+ .05
May	-1	-4	- .01	+ .15	- .16	+ .07
June	0	0	+ .02	+ .17	- .15	+ .10
July	+1	-1	- .01	+ .18	- .19	+ .08
August	0	-2	+ .09	+ .18	- .09	+ .13
September	-1	-4	- .07	+ .17	- .24	+ .05
October	+2	-1	- .02	+ .14	- .16	+ .06
November	+4	-1	+ .04	+ .18	- .14	+ .11
December	+3	0	+ .01	+ .12	- .11	+ .06
January 1958	-1	-6	.00	+ .21	- .21	+ .10
February	+1	-2	+ .07	+ .27	- .20	+ .17
March	+1	-2	- .08	+ .12	- .20	+ .02
Mean	0	-3	+0.01	+0.17	-0.16	+0.09
Wilson Beach, N. B.						
March 1957	-1	-10	-0.18	+0.03	-0.21	-0.08
April	-2	-10	- .23	.00	- .23	- .12
May	+3	- 6	- .13	+ .12	- .25	.00
June	+2	- 6	- .10	+ .10	- .20	.00
July	+2	-10	- .11	+ .09	- .20	- .01
August	0	-11	- .02	+ .18	- .20	+ .08
September	0	-10	- .17	+ .10	- .27	- .04
October	+3	- 8	- .10	+ .13	- .23	+ .02
November	+2	-10	- .14	+ .10	- .24	- .02
December	+3	- 9	- .04	+ .25	- .29	+ .10
January 1958	+4	- 7	- .13	+ .19	- .32	+ .03
February	+6	- 6	- .08	+ .24	- .32	+ .08
March	+2	-12	- .06	+ .19	- .25	+ .06
Mean	+2	- 9	-0.11	+0.13	-0.25	+0.01
Fairhaven, N. B.						
March 1957	+ 5	+5	+0.04	-0.44	+0.48	-0.20
April	+ 3	+3	- .04	- .45	+ .41	- .24
May	+ 1	+4	+ .09	- .29	+ .38	- .10
June	+ 4	+5	+ .06	- .36	+ .42	- .15
July	+ 4	+5	+ .11	- .29	+ .40	- .09
August	+ 5	+5	+ .14	- .30	+ .44	- .08
September	+ 5	+3	+ .03	- .32	+ .35	- .14
October	+ 9	+6	+ .06	- .30	+ .36	- .13
November	+10	+6	+ .03	- .34	+ .37	- .15
December	+ 7	+5	+ .04	- .29	+ .33	- .13
January 1958	+ 8	+3	- .01	- .32	+ .31	- .16
February	+ 6	+7	- .04	- .18	+ .22	- .07
March	+ 4	+2	+ .07	- .21	+ .28	- .07
Mean	+ 5	+5	+0.05	-0.31	+0.37	-0.13
St. Andrews, N. B.						
March 1957	+6	+8	+0.35	-0.47	+0.82	-0.06
April	+5	+6	+ .22	- .66	+ .88	- .22
May	+5	+6	+ .36	- .50	+ .86	- .07
June	+7	+9	+ .28	- .59	+ .87	- .16
July	+8	+9	+ .28	- .57	+ .85	- .14
August	+7	+7	+ .31	- .56	+ .87	- .12
Mean	+6	+8	+0.30	-0.56	+0.86	-0.13

TABLE 3-6

SUMMARY OF VELOCITY OBSERVATIONS

BY PASSAMAQUODDY SURVEY IN FEBRUARY 1957

Site no.*	Date	Time	Location	Maximum velocity, ft./sec.	Sounded depth, feet	Tide Range in feet, (Eastport)	Results of observations
1	2 Feb	0800 - 1130	Western Passage	5.3	115	17.8	Poor
1	20 Feb	1030 - 2130	Western Passage	5.0	145	17.4	Excellent
2	4 Feb	1430 - 1945	Eastport	5.1	100	16.8	Very Good
2	5 Feb	1415 - 2145	Eastport	5.2	245	16.3	Very Good
3	7 Feb	1015 - 1245	Pope Islet	2.9	180	14.4	Very Poor
3	21 Feb	0115 - 1700	Pope Islet	3.5	180	17.0	Very Good
4	8 Feb	1215 - 2245	Pope Islet	2.8	105	13.7	Excellent
5	9 Feb	1110 - 1800	Pope Islet	2.6	45	15.0	Good
6	11 Feb	0130 - 1645	Lubec Narrows	4.7	16	17.7	Poor
6	12 Feb	0645 - 1330	Lubec Narrows	7.4	45	20.5	Very Good
7	14 Feb	1115 - 2215	Little Letite Passage	5.5	70	24.7	Good
8	18 Feb	1400 - 0120	Letite Passage	9.9	60	23.0	Excellent

*Locations are shown on plate 3-28.

APPENDIX 3

PLATES

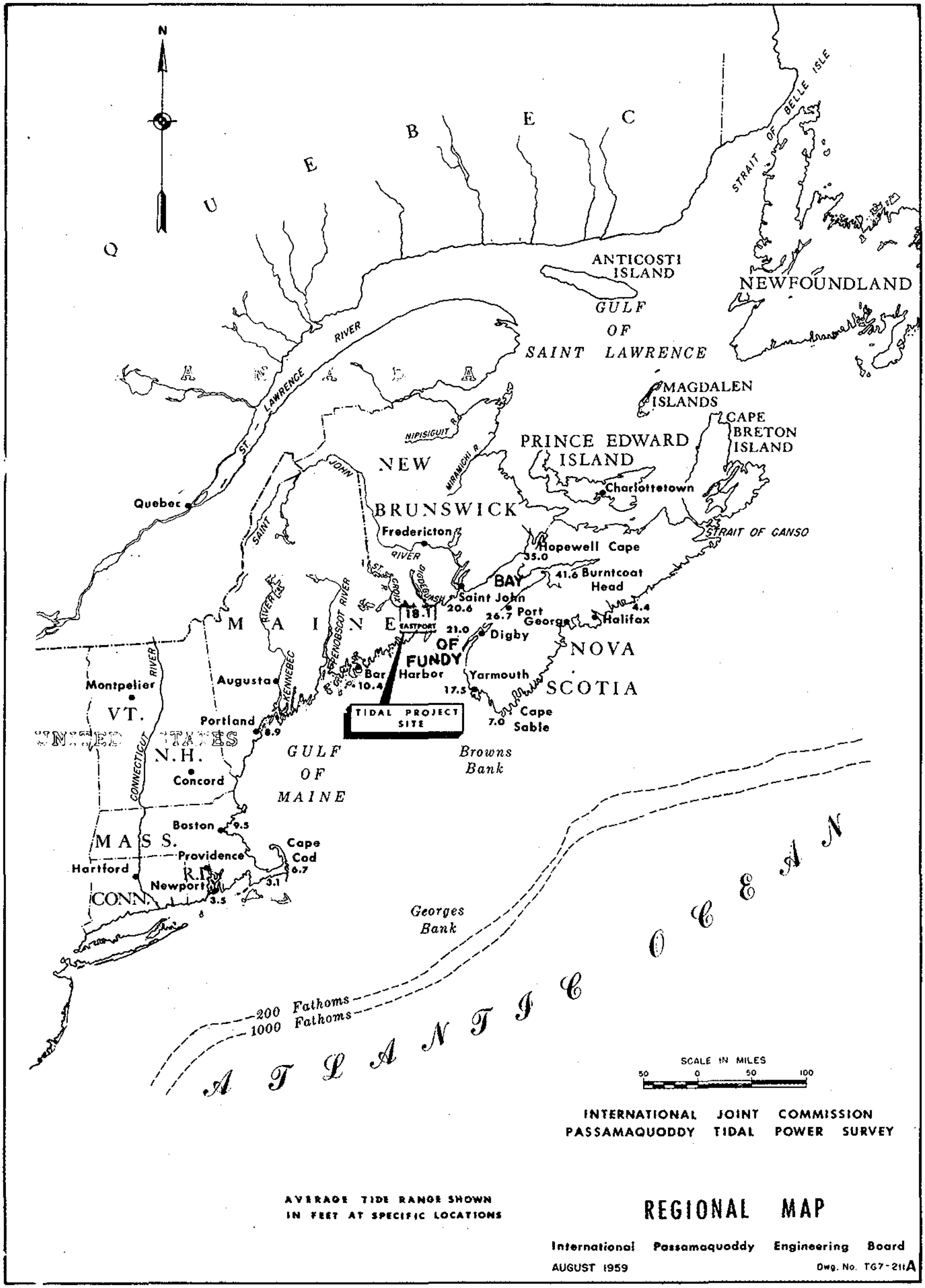
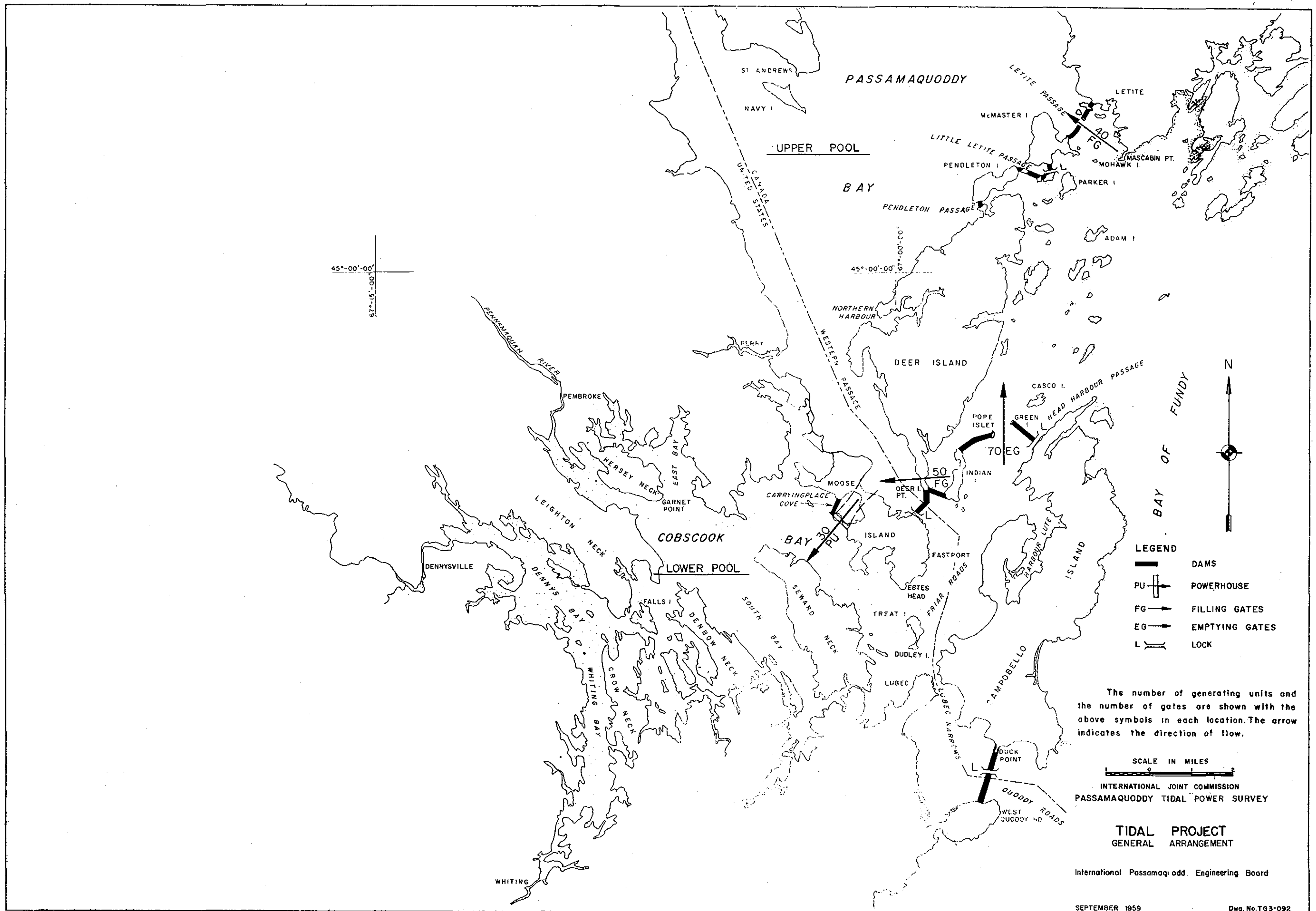

N
QUEBEC
CANADA
ST. LAWRENCE RIVER
ANTICOSTI ISLAND
GULF OF SAINT LAWRENCE
NEWFOUNDLAND
STRAIT OF BELLE ISLE
MAGDALEN ISLANDS
CAPE BRETON ISLAND
PRINCE EDWARD ISLAND
Charlottetown
STRAIT OF CANSO
NIPISIGUIT R.
MIRAMICHI R.
NEW BRUNSWICK
Quebec
SAINT JOHN RIVER
Fredericton
ST. CROIX
DIGDEGUASH
Hopewell Cape
35.0
41.6 Burntcoat Head
BAY OF FUNDY
Saint John
20.6
18.1
EASTPORT
26.7
Port George
4.4
Halifax
21.0
Digby
NOVA SCOTIA
Yarmouth
17.5
Cape Sable
7.0
MAINE
KENNEBEC RIVER
PENOBSCOT RIVER
Augusta
Bar Harbor
10.4
TIDAL PROJECT SITE
Montpelier
VT.
CONNECTICUT RIVER
UNITED STATES
Portland
8.9
N.H.
Concord
GULF OF MAINE
Browns Bank
Boston
9.5
MASS.
Cape Cod
6.7
Providence
R.I.
Hartford
Newport
3.1
CONN.
3.5
Georges Bank
200 Fathoms
1000 Fathoms
ATLANTIC OCEAN
SCALE IN MILES
50 0 50 100
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
AVERAGE TIDE RANGE SHOWN IN FEET AT SPECIFIC LOCATIONS
REGIONAL MAP
International Passamaquoddy Engineering Board
AUGUST 1959
Dwg. No. TG7-211A

PLATE 3-1



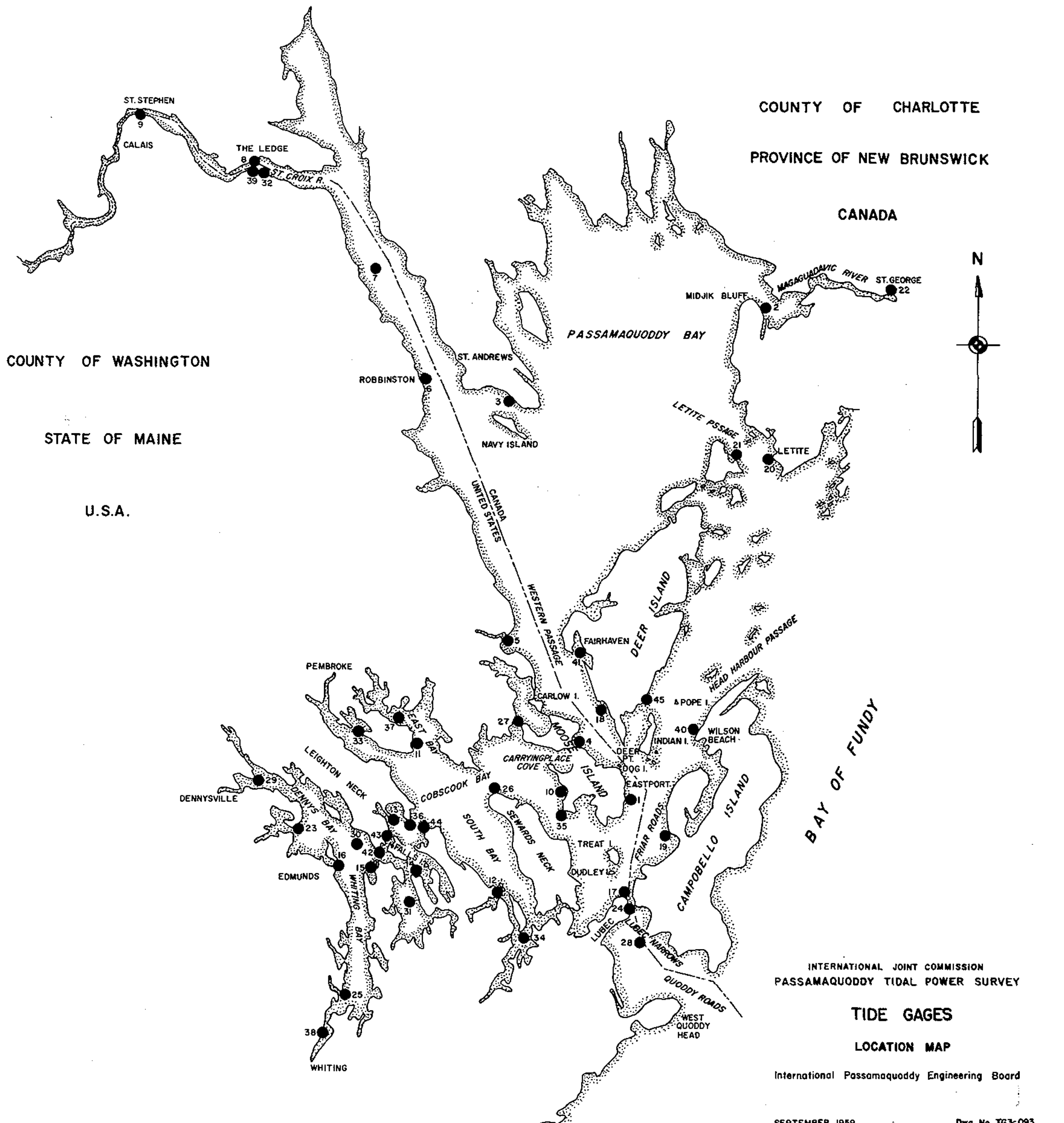
PASSAMAQUODDY
BAY
UPPER POOL
COBSCOOK
BAY
LOWER POOL
BAY OF FUNDY
ST ANDREWS
NAVY I
LETITE PASSAGE
LETITE
McMASTER I
LITTLE LETITE PASSAGE
PENDLETON I
MASCABIN PT.
MOHAWK I
PARKER I
PENDLETON PASSAGE
ADAM I
CANADA
UNITED STATES
WESTERN PASSAGE
NORTHERN HARBOUR
DEER ISLAND
CASCO I.
HEAD HARBOUR PASSAGE
POPE ISLET
GREEN I
INDIAN I
DEER I. PT.
MOOSE
ISLAND
CARRYINGPLACE COVE
EASTPORT
ESTES HEAD
FRIAR ROADS
TREAT I
DUDLEY I.
LUBEC
LUBEC NARROWS
CAMPOBELLO
ISLAND
HARBOUR LUTE
DUCK POINT
QUODDY ROADS
WEST QUODDY HD
PENNAMAQUAN RIVER
PEMBROKE
HERSEY NECK
EAST BAY
GARNET POINT
LEIGHTON NECK
DENNYSVILLE
DENNYS BAY
FALLS I
DENBOW NECK
SOUTH BAY
SEWARD NECK
WHITING BAY
CROW NECK
WHITING
45°-00'-00"
67°-15'-00"
67°-00'-00"
40 FG
50 FG
70 EG
30 PU
L
N
LEGEND
DAMS
PU POWERHOUSE
FG FILLING GATES
EG EMPTYING GATES
L LOCK
The number of generating units and the number of gates are shown with the above symbols in each location. The arrow indicates the direction of flow.
SCALE IN MILES
0 1 2
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL PROJECT
GENERAL ARRANGEMENT
International Passamaquoddy Engineering Board
SEPTEMBER 1959
Dwg. No. TG3-092

OBSERVATIONS OF TIDAL STAGES

KEY NO.	LOCATION OR NAME OF GAGE	TYPE OF GAGE	PERIOD OF RECORD DATE	PERIOD OF RECORD LENGTH	AGENCY
1	EASTPORT, FRIAR ROADS		1918	2 MOS.	C. & G.S.
1	"	S	1928	1/2 MO.	COOPER
1	"	R	1929-57	27 YRS.	C. & G.S.
1	"	R	1957-58	1½ YRS.	C.E.
2	MIDJIK BLUFF, PASSAMAQUODDY BAY		1918	1/2 MO.	C. & G.S.
3	ST. ANDREWS, PASSAMAQUODDY BAY		1918	1 MO.	C. & G.S.
3	" " " "	S	1924	1 WEEK	COOPER
3	" " " "	S	1926	1 WEEK	COOPER
3	" " " "	R	1957	6 MOS.	C.E.
4	JOHNSON COVE, MOOSE ISLAND		1887	2H, 2L	C. & G.S.
5	GLEASON COVE, PASSAMAQUODDY BAY		1887	1/2 MO.	C. & G.S.
5	" " " "	R	1935-36	7 MOS.	C.E.
6	ROBBINSTON, ST. CROIX RIVER		1887	1 MO.	C. & G.S.
7	ST. CROIX I., ST. CROIX RIVER		1887	8H, 10L	C. & G.S.
8	THE LEDGE, ST. CROIX RIVER		1887	4H, 4L	C. & G.S.
9	CALAIS, ST. CROIX RIVER		1841	1 MO.	C. & G.S.
10	DEEP COVE, MOOSE ISLAND		1887	7H, 5L	C. & G.S.
10	" " " "		1888	2H, 2L	C. & G.S.
11	EAST BAY		1888	1/2 MO.	C. & G.S.
12	MORAN HEAD, SOUTH BAY		1887	4H, 4L	C. & G.S.
13	LEIGHTON NECK		1888	9H, 10L	C. & G.S.
14	COFFIN POINT		1888	15H, 13L	C. & G.S.
15	RAFT COVE		1888	4H, 3L	C. & G.S.
15	" "	R	1935	1 MO.	C.E.
16	BIRCH ISLANDS		1888	1 MO.	C. & G.S.
16	EDMUNDS	R	1958	1 MO.	C.E.
17	LUBEC		1861	1/3 MO.	C. & G.S.
17	"		1877	1 MO.	C. & G.S.
17	LUBEC CUSTOM HOUSE	R	1935-36	1 YR.	C.E.
17	LUBEC	R	1951	1 MO.	G.S.
18	CUMMINGS COVE, DEER ISLAND	S	1924	1 MO.	COOPER
18	" " " "	S	1926	9 MO.	COOPER
18	" " " "	R	1951	1 MO.	G.S.
19	WELSHPOOL	S	1924-25	2 MOS.	COOPER
19	"	S	1926	5 MO.	COOPER
19	"	S	1927	1/3 MO.	COOPER
20	LETITE	S	1924	1 MO.	COOPER
20	"	S	1927	1 MO.	COOPER
20	"	R	1951	1 MO.	G.S.
20	"	R	1957-58	1½ YRS.	C.E.
21	SHIP HARBOR, MACMASTER ISLAND	S	1927	1 WEEK	COOPER
22	ST. GEORGE, MAGAGUADAVIC RIVER	S	1928	1 MO.	COOPER
23	DENNYSVILLE	S	1926	1 WEEK	COOPER
24	NARROWS, LUBEC	S	1924	1/2 MO.	COOPER
25	GRAVEL POINT, WHITING BAY	R	1935-36	3 MOS.	C.E.
26	SEWARD NECK	R	1935-36	7 MOS.	C.E.
27	BAR HARBOR HIGHWAY BRIDGE	R	1935	2 MOS.	C.E.
28	LUBEC CHANNEL LIGHT	R	1935	1½ MOS.	C.E.
29	HINCKLEY POINT, DENNYS RIVER	R	1935	1 MO.	C.E.
30	DRAM ISLAND, WHITING BAY	R	1935	1 MO.	C.E.
31	STRAIGHT BAY	R	1935	3/4 MO.	C.E.
32	BREAKWATER, ST. CROIX RIVER	R	1935-36	1 MO.	C.E.
33	HERSEY COVE, PENNAMAQUAN RIVER	R	1935-36	1 MO.	C.E.
34	SCRUB ISLAND, SOUTH BAY	R	1935-36	1 MO.	C.E.
35	SHACKFORD HEAD, COBSCOOK BAY	R	1936	1 MO.	C.E.
36	LEIGHTON POINT	R	1936	1 MO.	C.E.
37	SIPP BAY	R	1936	2/3 MO.	C.E.
38	DINSMORE DOCK, WHITING, WHITING RIVER (DRY AT LOW WATER)	S	1935	1 MO.	C.E.
39	QUARANTINE, ST. CROIX RIVER	S	1935	1/2 MO.	C.E.
40	WILSON BEACH	R	1957-58	1½ YRS.	C.E.
41	FAIRHAVEN	R	1957-58	1½ YRS.	C.E.
42	FALLS	R	1957	1 MO.	C.E.
43	NECK	R	1957	1 MO.	C.E.
44	DENBOW	R	1957-58	1 MO.	C.E.
45	CHOCOLATE COVE, DEER ISLAND	R	1951	1 MO.	G.S.

EXPLANATION OF ABBREVIATIONS:

S	STAFF GAGE
R	RECORDING GAGE
H	HIGH WATERS
L	LOW WATERS
C. & G.S.	UNITED STATES COAST AND GEODETIC SURVEY.
COOPER	DEXTER P. COOPER, INC.
C.E.	CORPS OF ENGINEERS, U.S. ARMY.
G.S.	UNITED STATES GEOLOGICAL SURVEY.



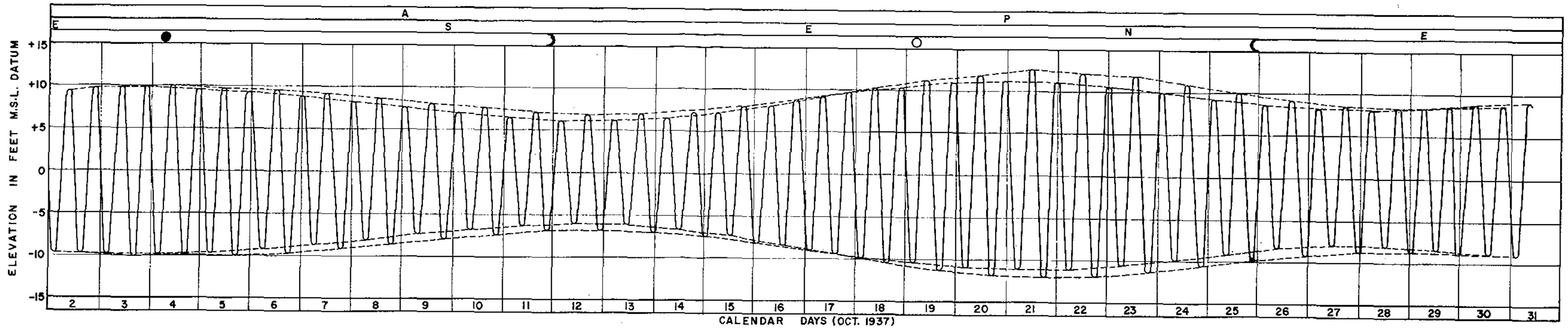
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDE GAGES

LOCATION MAP

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-093



NOTE:
THIS CURVE IS BASED ON PREDICTED TIDES.

FIGURE 1 — TYPICAL MONTH OF TIDES

SYMBOL EXPLANATION	
● NEW MOON	E MOON ON THE EQUATOR
☽ FIRST QUARTER	N MOON FARTHEST NORTH OF EQUATOR
○ FULL MOON	S MOON FARTHEST SOUTH OF EQUATOR
☾ LAST QUARTER	A APOGEE - MOON FARTHEST FROM THE EARTH.
	P PERIGEE - MOON NEAREST TO THE EARTH.

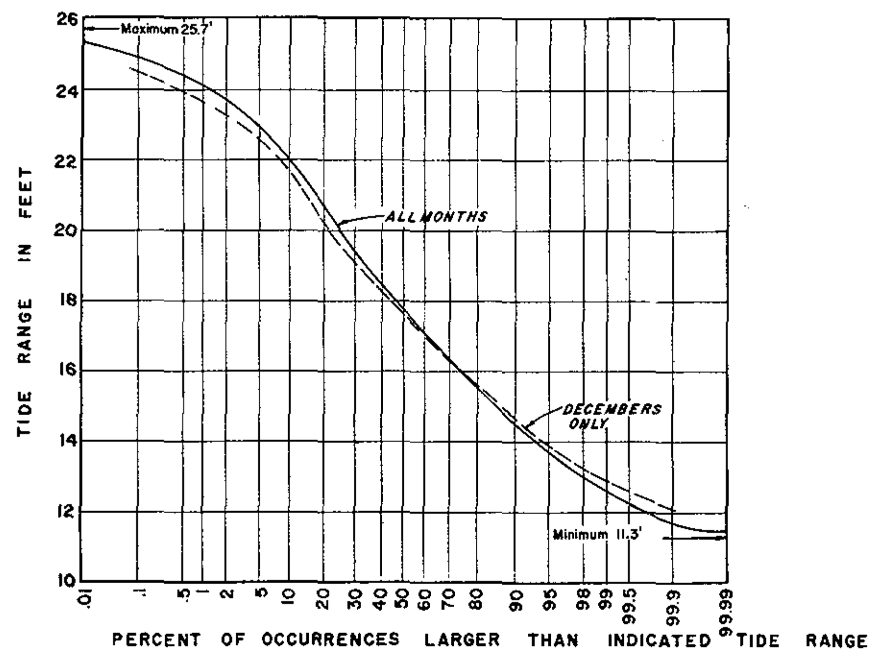


FIGURE 2 — TIDE RANGE OCCURRENCE CURVE

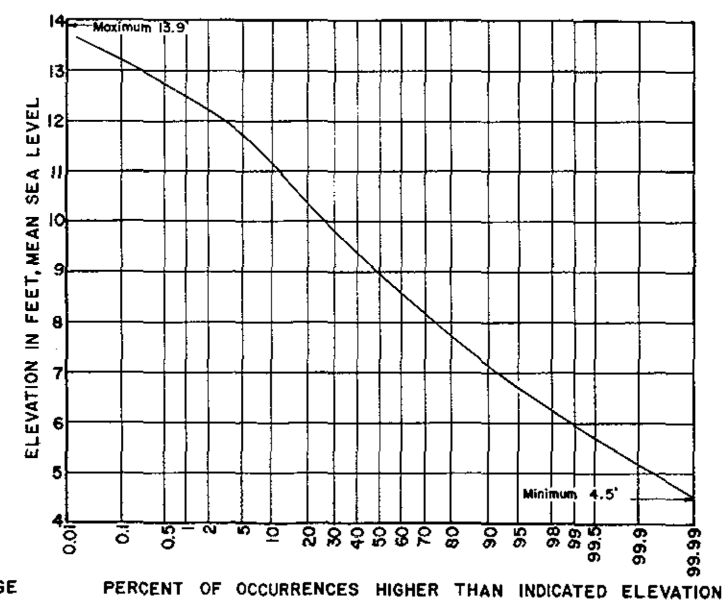


FIGURE 3 — HIGH TIDE ELEVATION OCCURRENCE CURVE

NOTE:
OCCURRENCE CURVES ARE BASED ON 19-YEARS OF OBSERVED TIDES AT EASTPORT, MAINE.

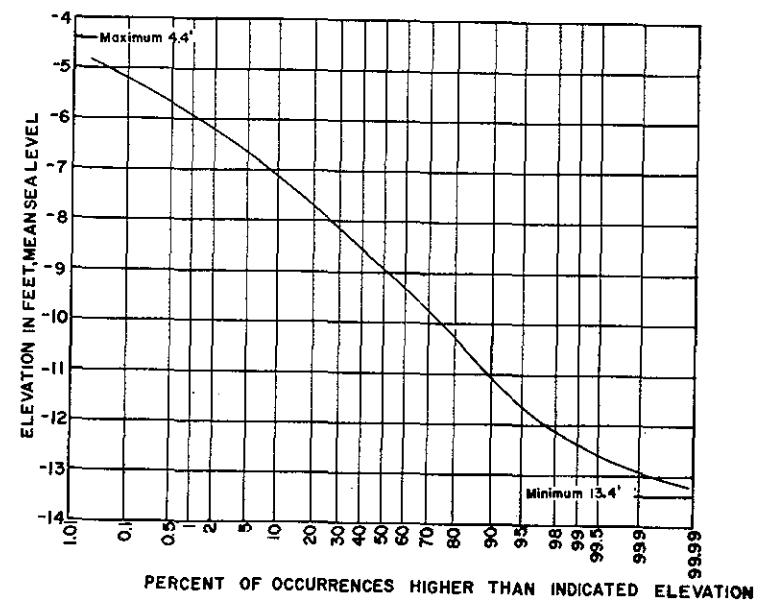


FIGURE 4 - LOW TIDE ELEVATION OCCURRENCE CURVE

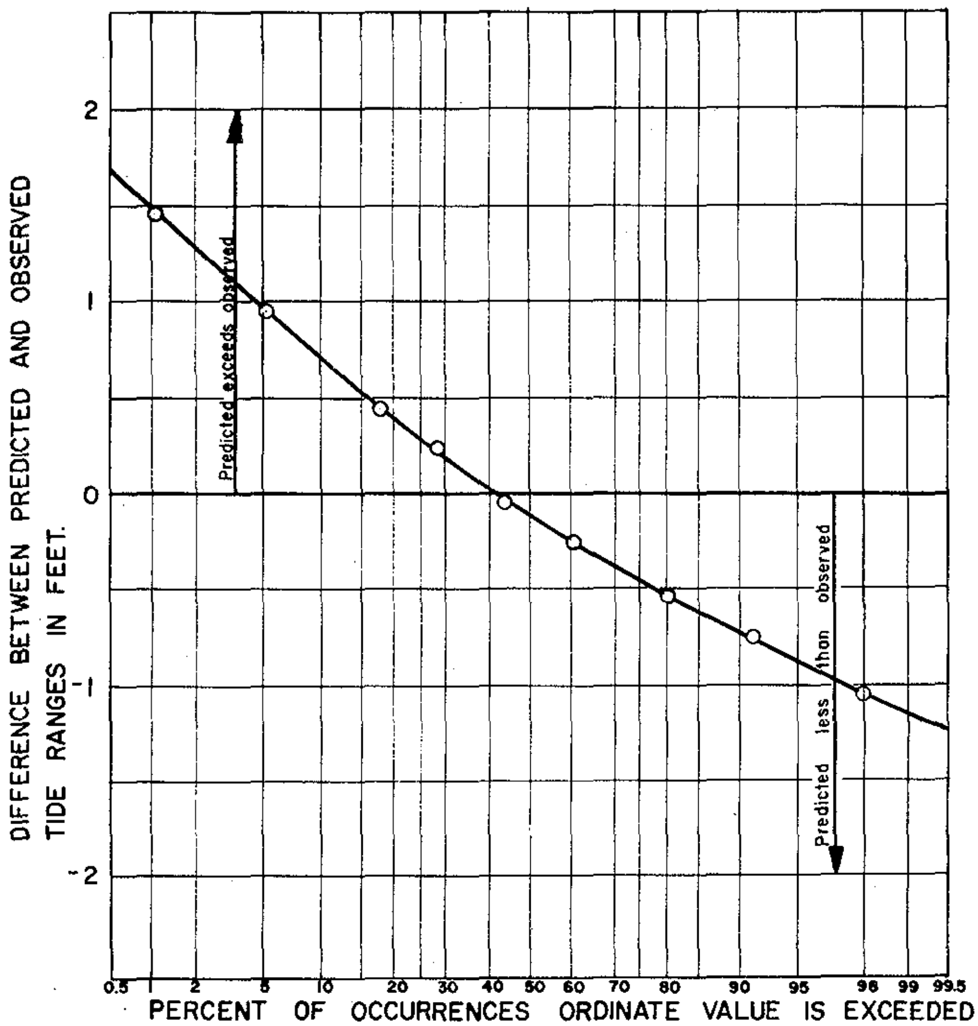
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDE RANGE AND HEIGHT

EASTPORT, MAINE

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-094



NOTE:

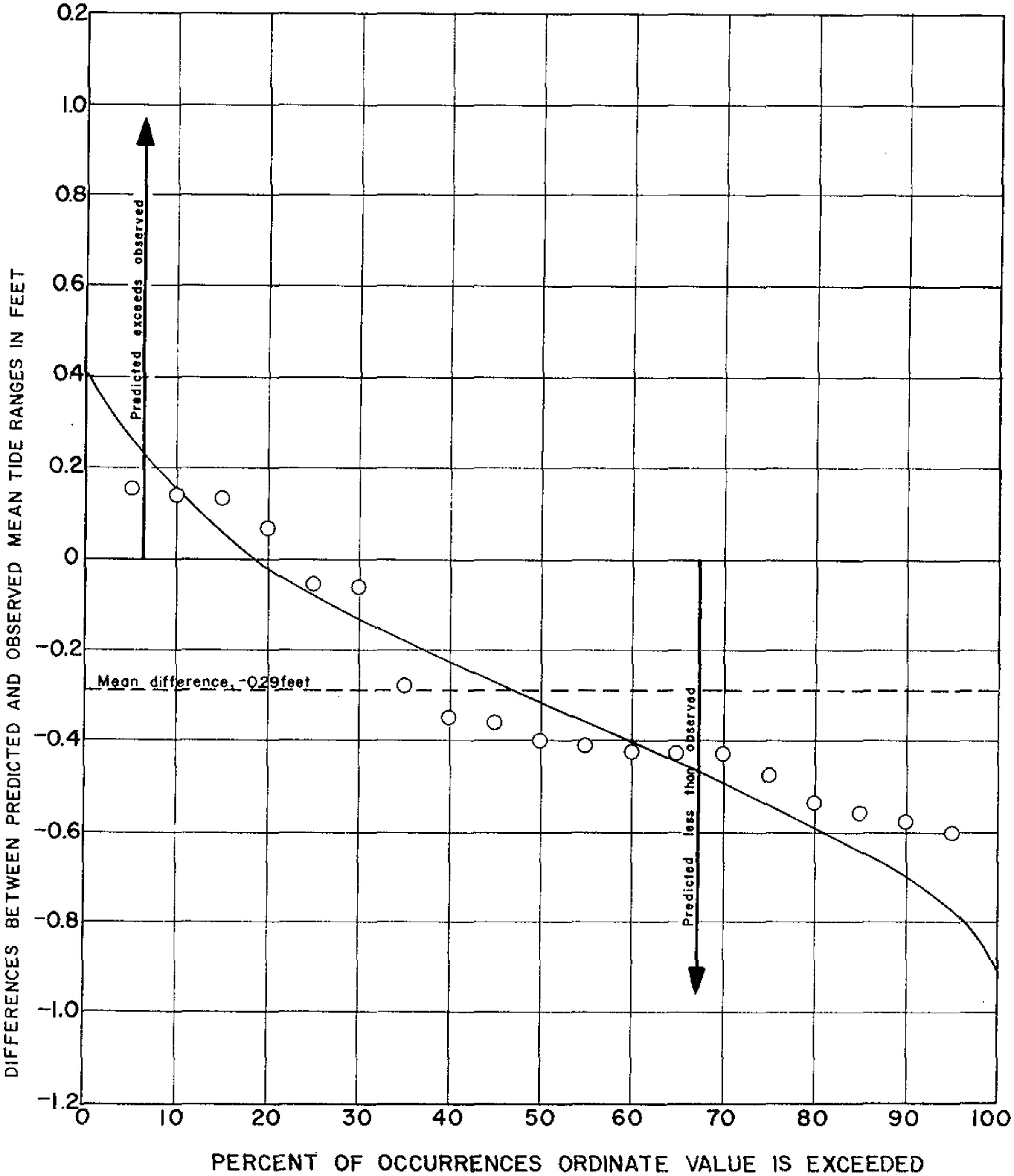
Curve is based on comparison of predicted and observed tide ranges for the year 1940.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

**INDIVIDUAL TIDE RANGES
PREDICTED MINUS OBSERVED
EASTPORT, MAINE, 1940**

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-095



LEGEND:

MONTHLY

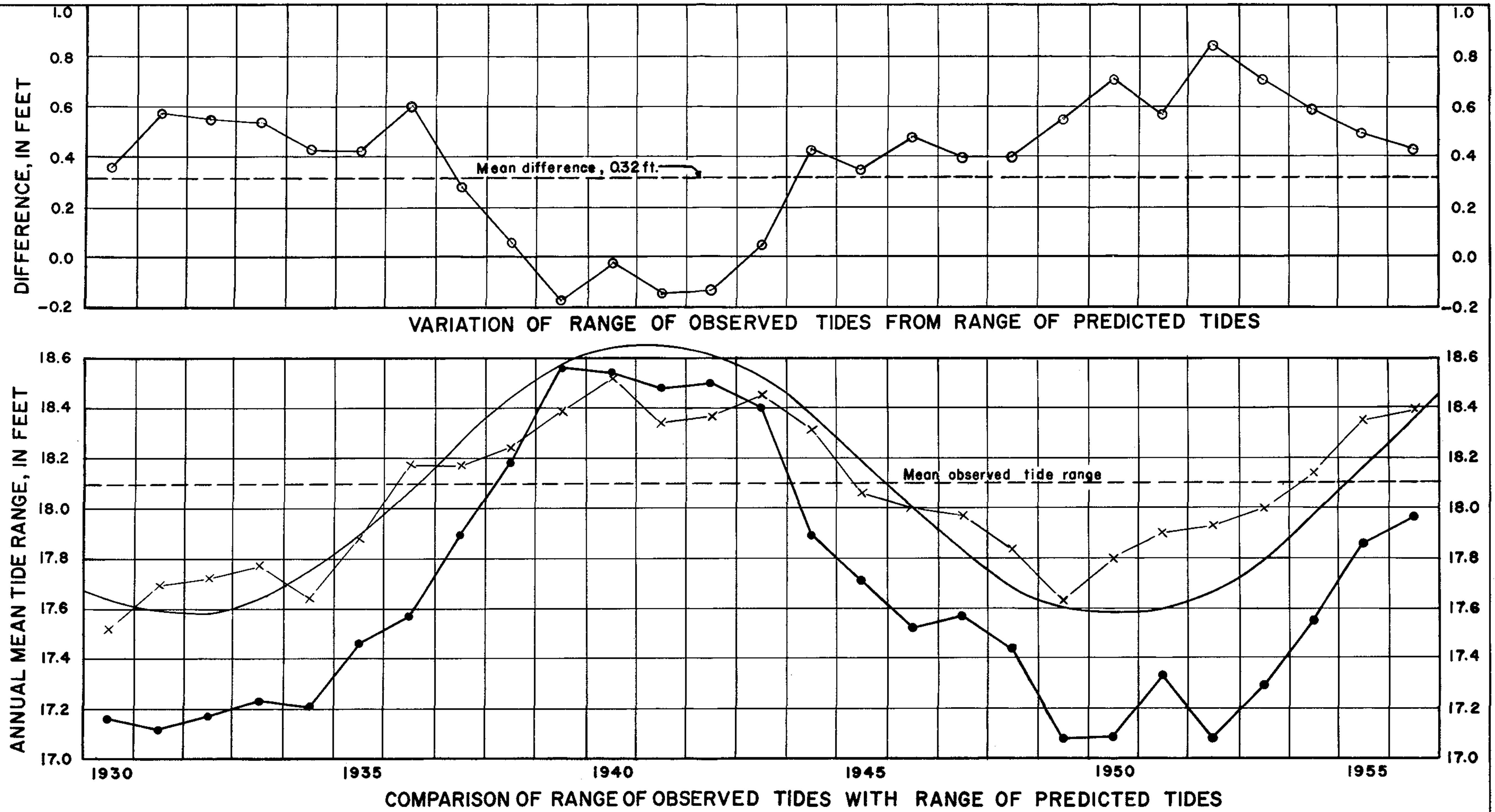
O ANNUAL

NOTE:

Data are based on tide predictions and observations at Eastport, Maine, for the 19-year period, 1930 through 1948.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
MONTHLY MEAN TIDE RANGES
PREDICTED MINUS OBSERVED
EASTPORT, MAINE, 1930-1948
International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-096



LEGEND:

● PREDICTED (Mean range, 17.78 feet, average of two 19 year periods, 1930-48 and 1938-56)

X OBSERVED (Mean range, 18.10 feet, " " " " " " " ")

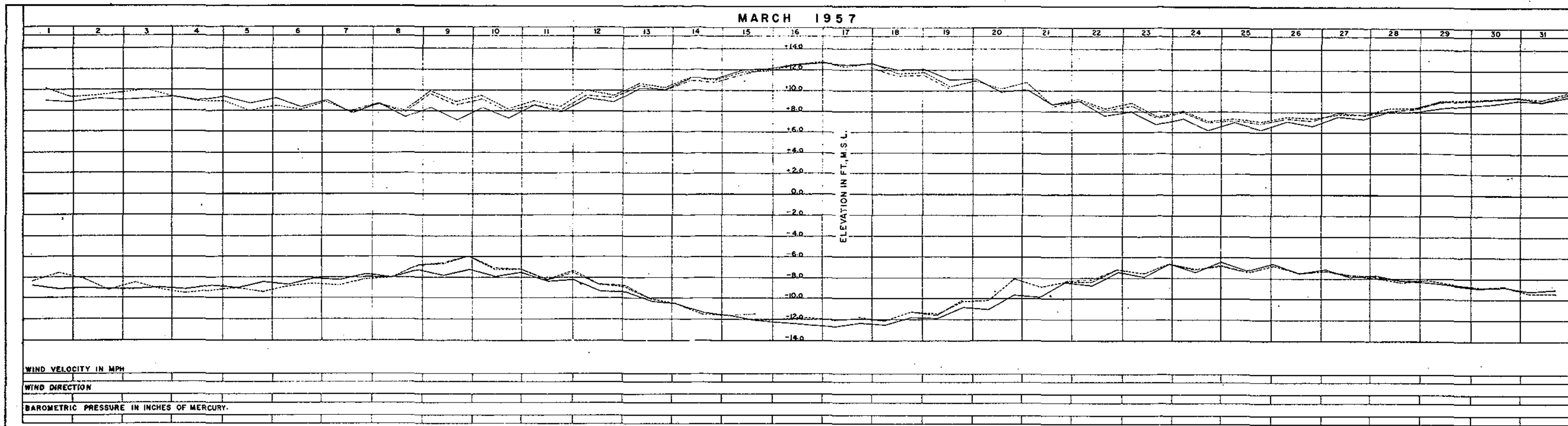
ESTIMATED TIDE RANGE (on basis of mean observed tide range and longitude of moon's node)

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

ANNUAL MEAN TIDE RANGES
EASTPORT, MAINE, 1930-1956

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-097

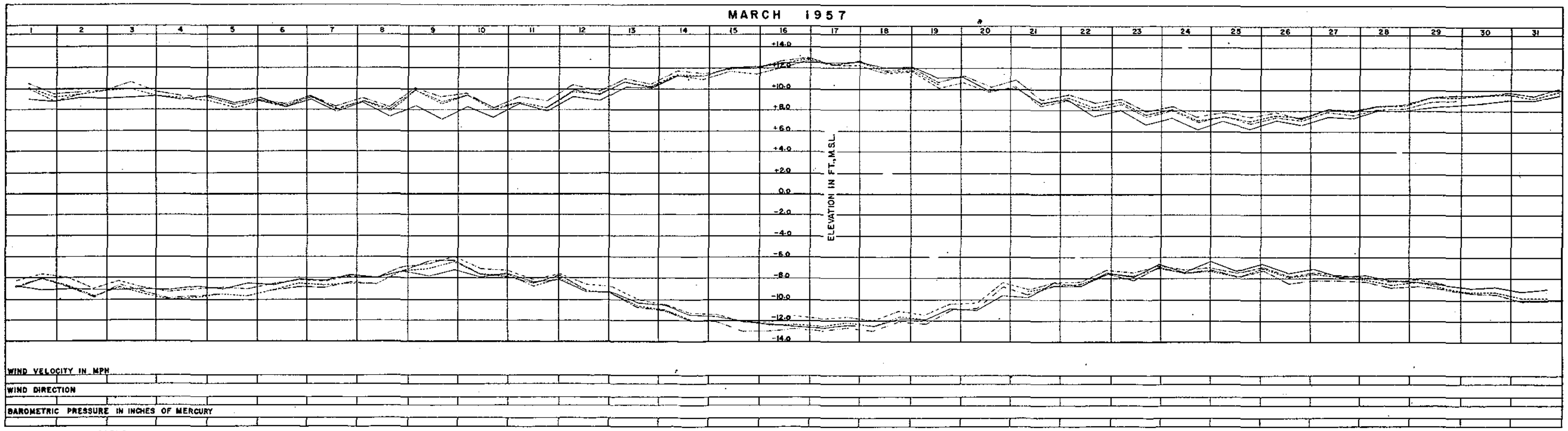


LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Eastport, Maine
- Wilsons Beach, New Brunswick

NOTES

(Wilsons Beach) 15:57-15 to 23:57-17- No Record
19·21-19 to 14:30-21- No Record
09.24-2/27 to 14:20-3/7-No Record



LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Fairhaven, New Brunswick
- Letite, New Brunswick
- St. Andrews, New Brunswick

NOTES

(Letite) 15·54-29 to 23.05-31- No Record
(Fairhaven) 13·25-19 to 08.52-21- No Record

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

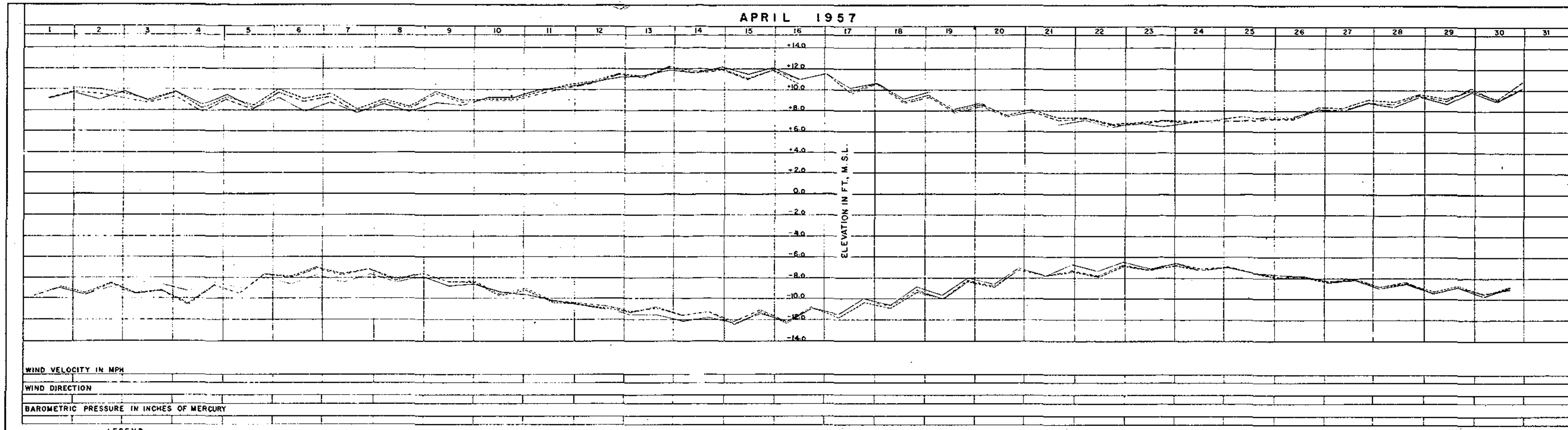
OBSERVED HIGH AND LOW TIDES

MARCH 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. TG3-074



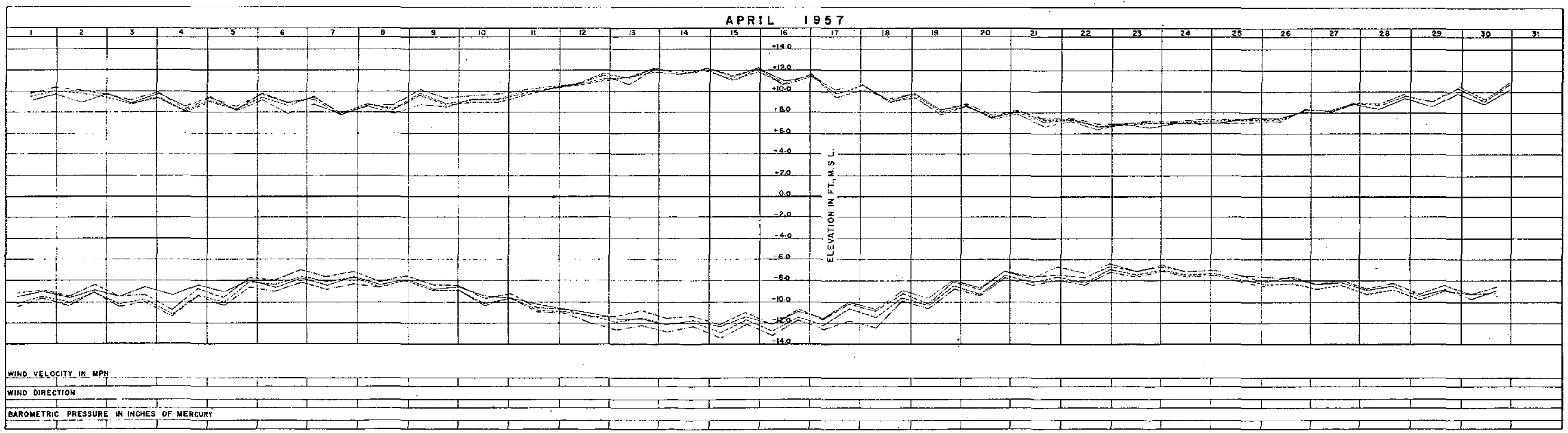
LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Eastport, Maine
- Wilsons Beach, New Brunswick

NOTES

(Eastport) 00:00-1 to 17:35-1 No Record
07:36-25 to 19-49-25 No Record

(Wilsons Beach) 12:00-16 to 12:35-17 No Record



LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Fairhaven, New Brunswick
- Letite, New Brunswick
- St. Andrews, New Brunswick

NOTES

(Fairhaven) 04:16-29 to 16:36-29 No Record

(St. Andrews) 06:30-26 to 17:16-30 No Record

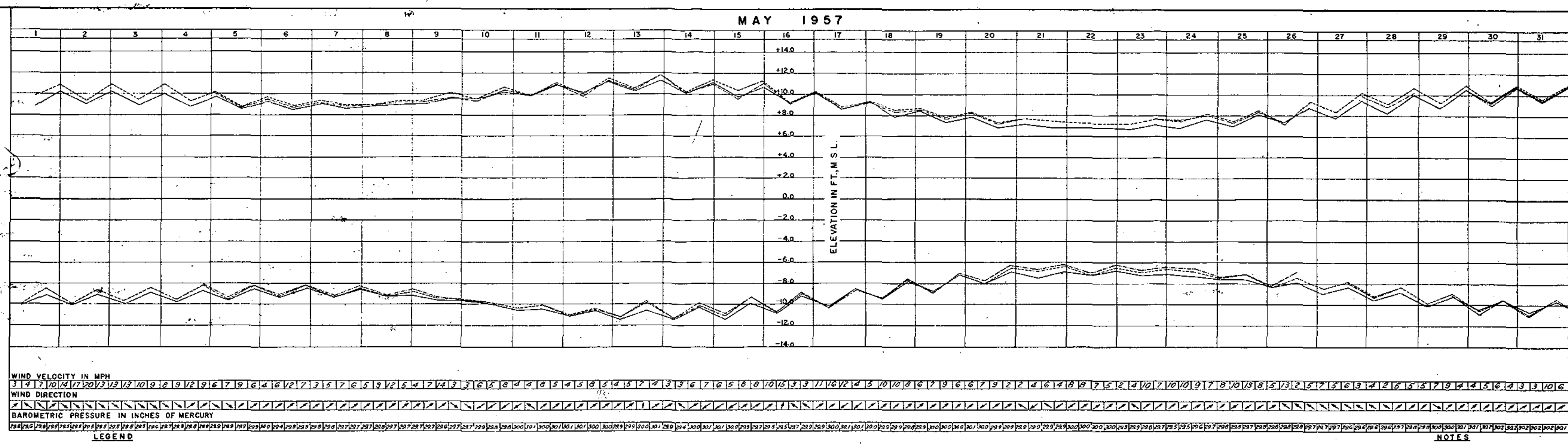
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

APRIL 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. T93-075

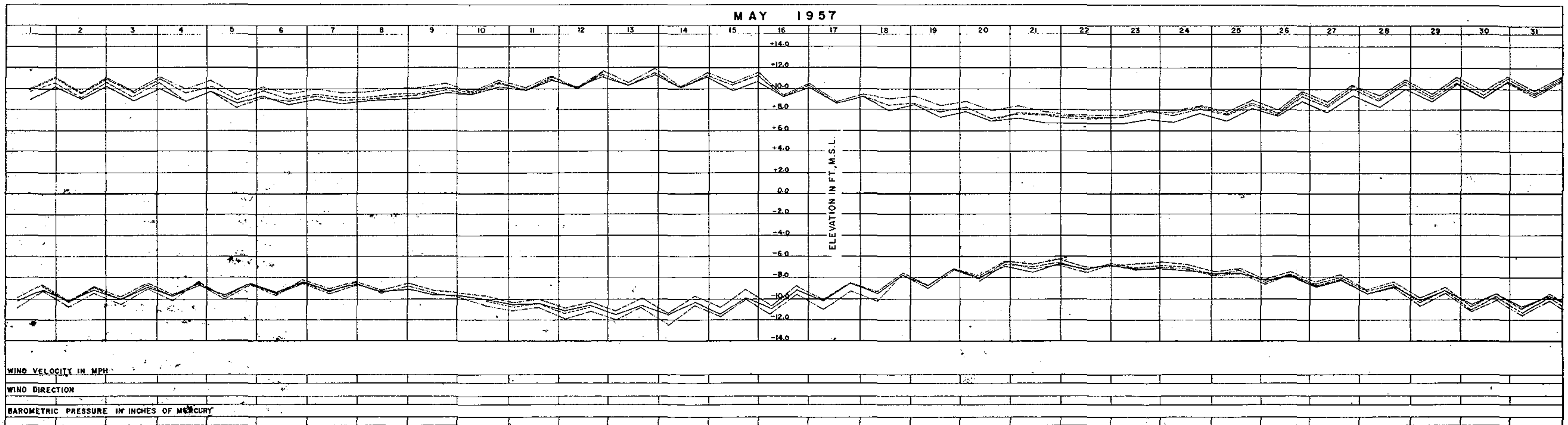


LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.&G.S.)
- - - - - - Eastport, Maine
- —·—·— Wilsons Beach, New Brunswick

NOTES

—·—·— (Wilsons Beach) 00:00- 1 to 20:05-4 - No Record
08:24-26 to 14:21-26 - No Record
14:21-26 to 21:07-27 - No Record
22:05-28 to 16:39-29 - No Record



LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.&G.S.)
- - - - - - Fairhaven, New Brunswick
- —·—·— Letite, New Brunswick
- —··—··— St. Andrews, New Brunswick

NOTES

- - - - - (Fairhaven) 00:00- 1 to 11:21- 1 - No Record
05:08- 8 to 17:57- 8 - No Record
06:24- 9 to 19:00- 9 - No Record
07:21- 10 to 19:48-10 - No Record
21:37-12 to 09:41-20 - No Record

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

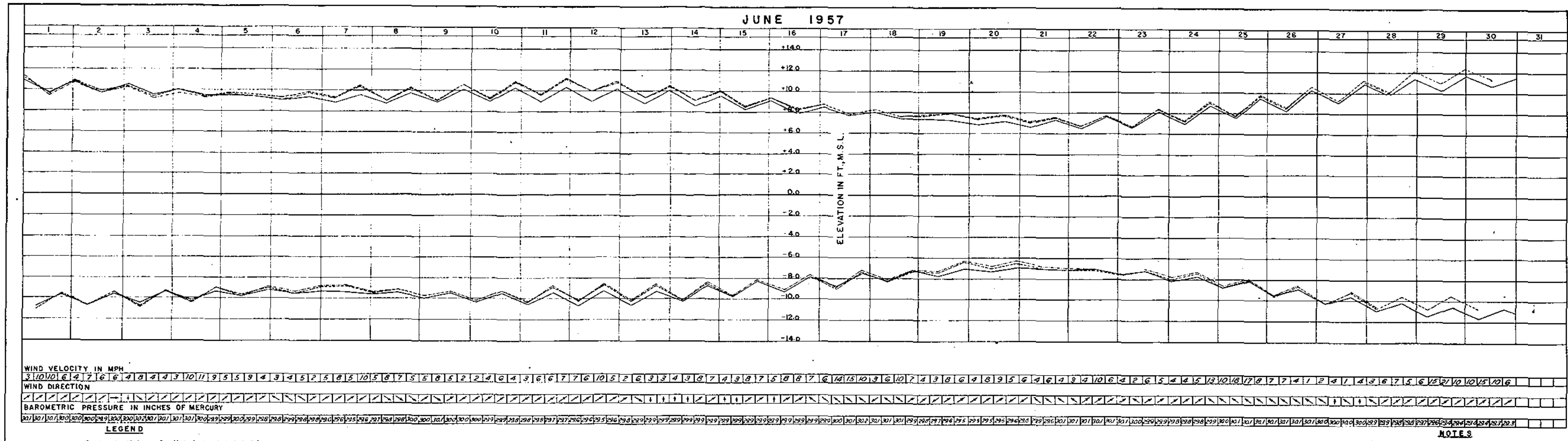
OBSERVED HIGH AND LOW TIDES

MAY 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. 783-076

PLATE 3-10



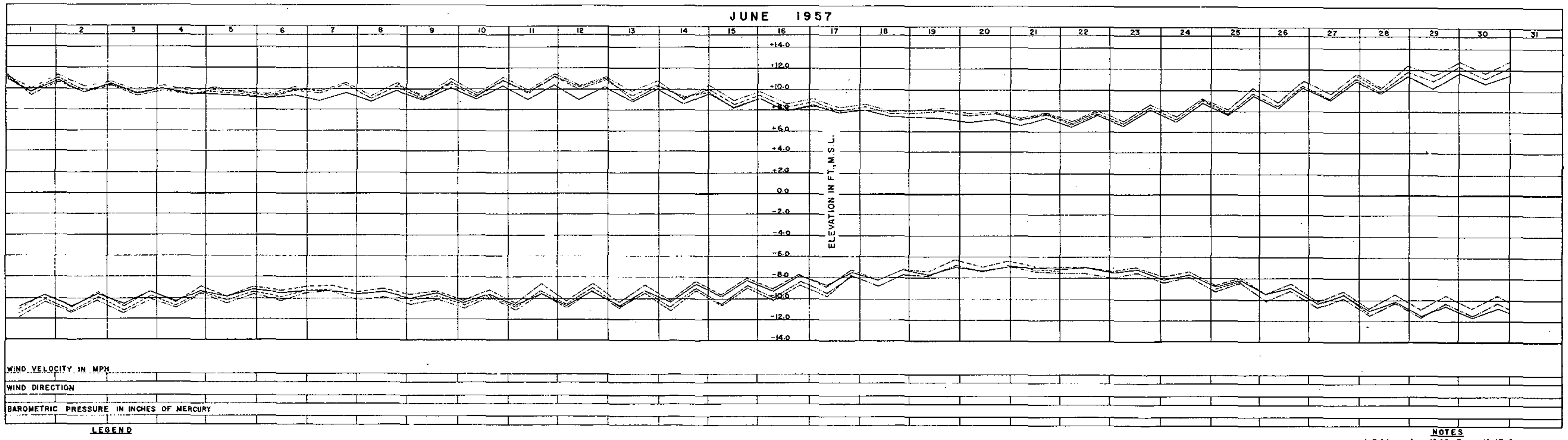
LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.&G.S.)
- - - - - - - Eastport, Maine
- -·-·-·- Wilsons Beach, New Brunswick

NOTES

- - - - - - - (Eastport) 12:21-30 to 00:00-30- No Record

-·-·-·- (Wilsons Beach) 21:30-26 to 16:25-27- No Record
11:07-28 to 12:15-30- No Record



LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.&G.S.)
- - - - - - - Fairhaven, New Brunswick
- -·-·-·- Letite, New Brunswick
- -··-··- St. Andrews, New Brunswick

NOTES

- - - - - - - (Fairhaven) 12:25-7 to 19:47-8 - No Record
20:40-17 to 16:30-20- No Record
18:05-22 to 19:57-24- No Record
14:39-25 to 15:30-26- No Record
15:30-26 to 22:26-27- No Record
11:00-28 to 00:00-30- No Record

INTERNATIONAL JOINT COMMISSION

PASSAMAQUODDY TIDAL POWER SURVEY

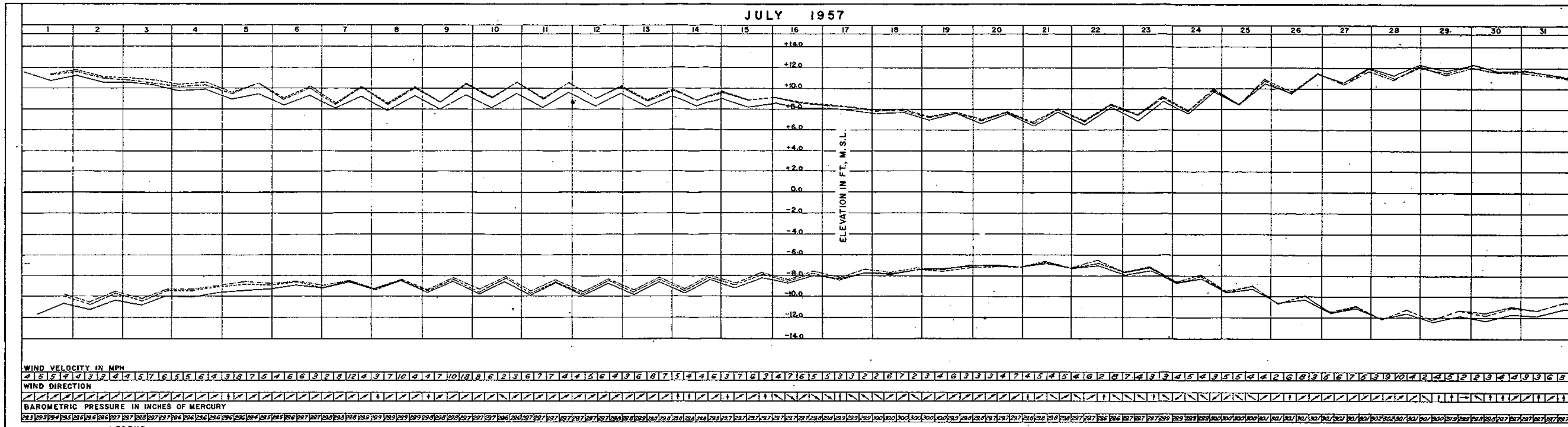
OBSERVED HIGH AND LOW TIDES

JUNE 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. TG3-077

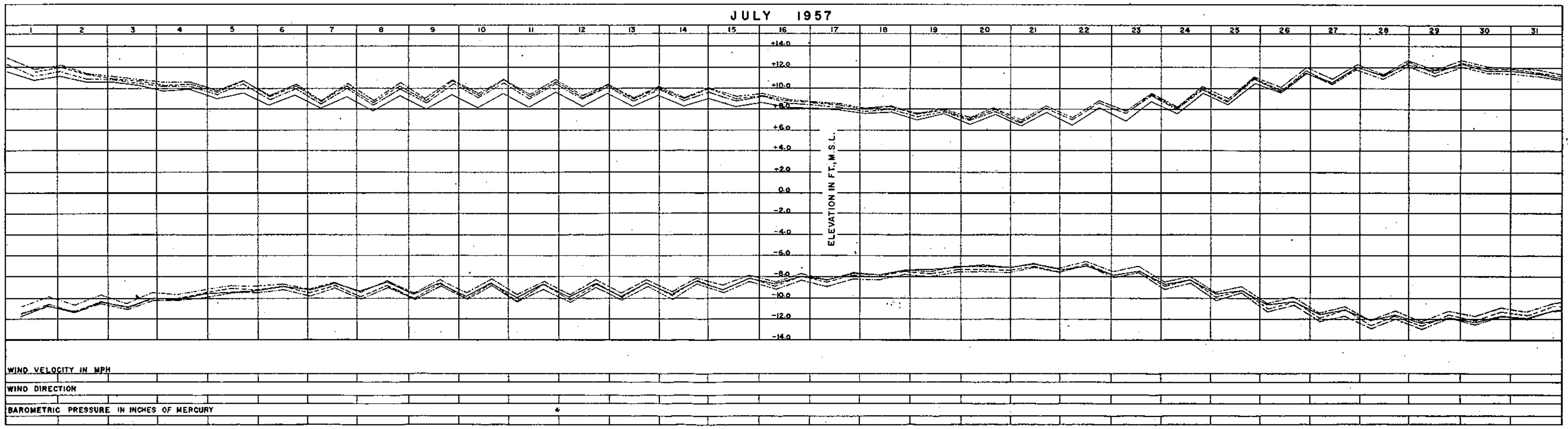


LEGEND

- ——— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - Eastport, Maine
- —·—·— Wilsons Beach, New Brunswick

NOTES

(Eastport) 00:00-1 to 13:19-1 - No Record
(Wilsons Beach) 00:00-1 to 13:18-1 - No Record



LEGEND

- ——— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - Fairhaven, New Brunswick
- —·—·— Letite, New Brunswick
- —··—·· St. Andrews, New Brunswick

NOTES

(Fairhaven) 00:00-1 to 07:28-1 - No Record

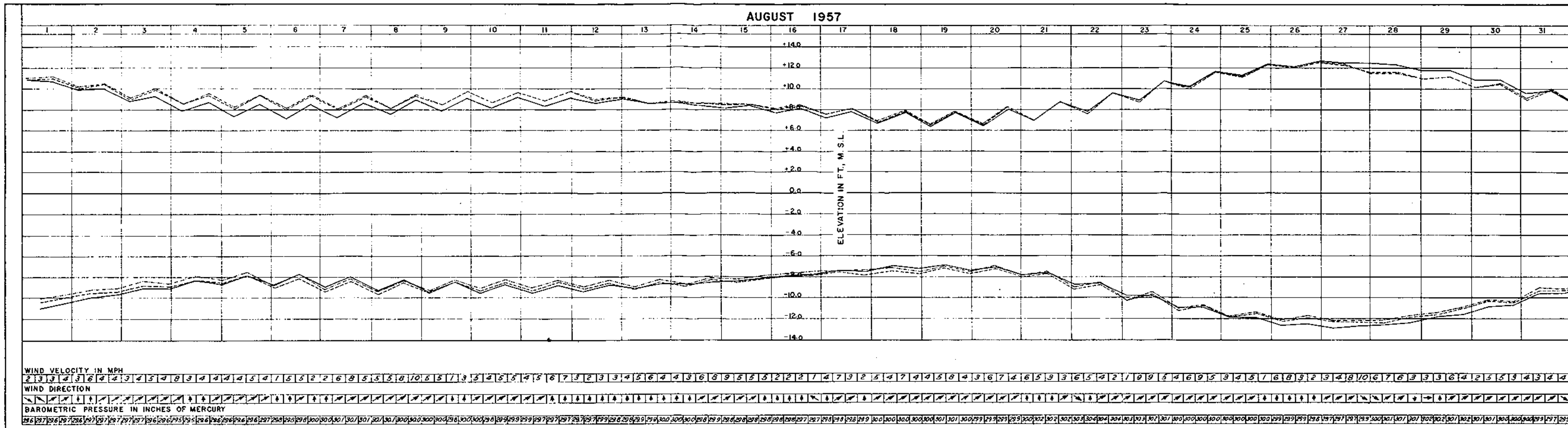
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

JULY 1957

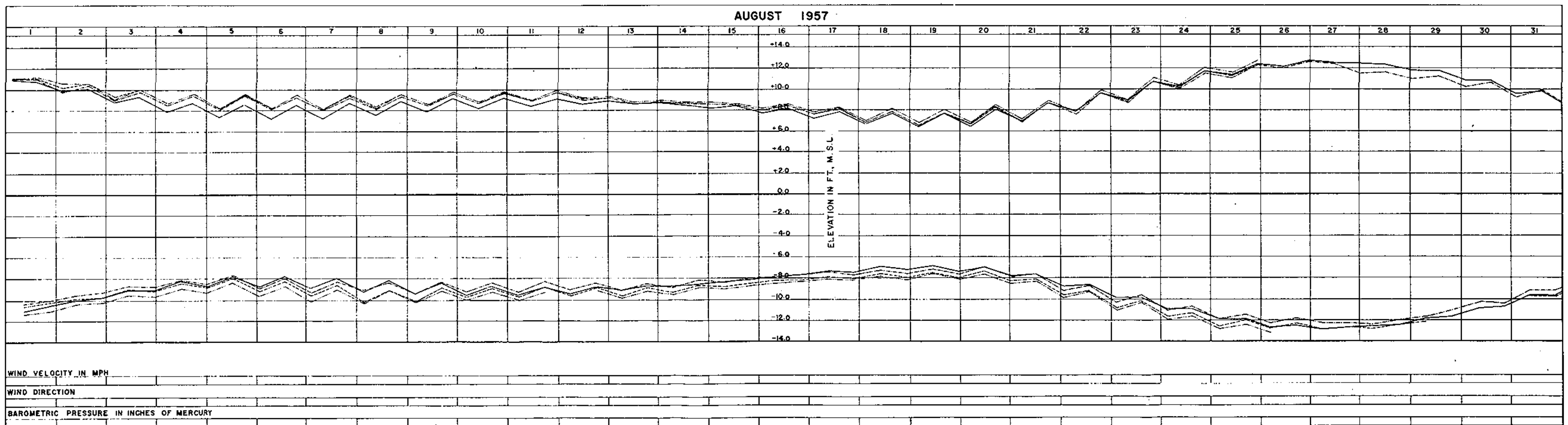
International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-078



LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Eastport, Maine
- Wilsons Beach, New Brunswick



LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Fairhaven, New Brunswick
- Letite, New Brunswick
- St. Andrews, New Brunswick

NOTES

(Fairhaven) 13:39-29 to 9:29-31 No Record
(St. Andrews) 12:04-12 to 18:22-12 No Record
09:05-26 Gage Removed

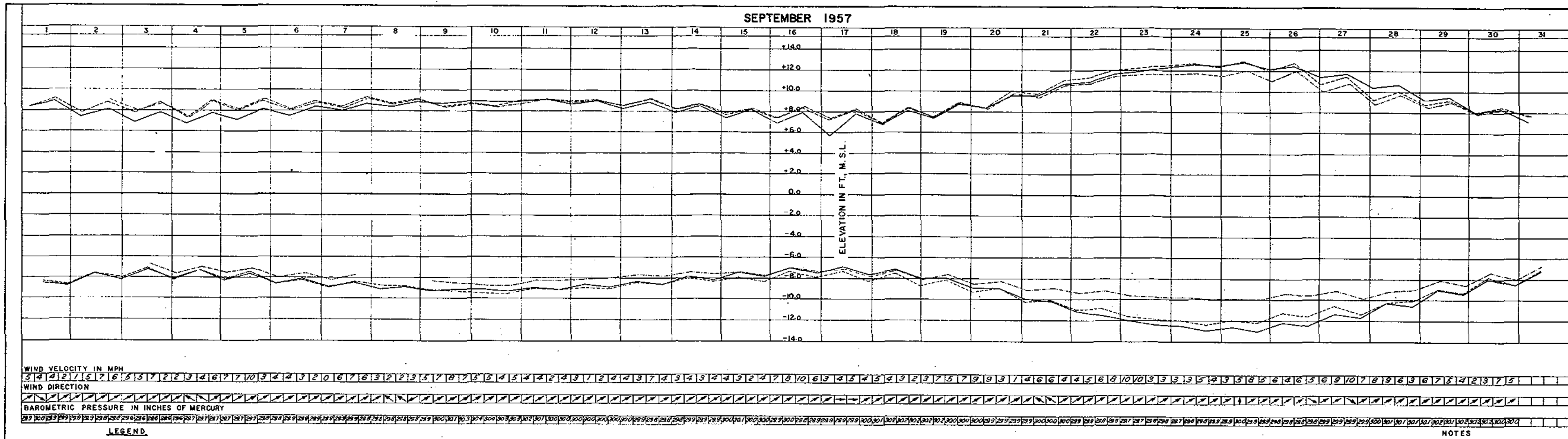
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

AUGUST 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-079

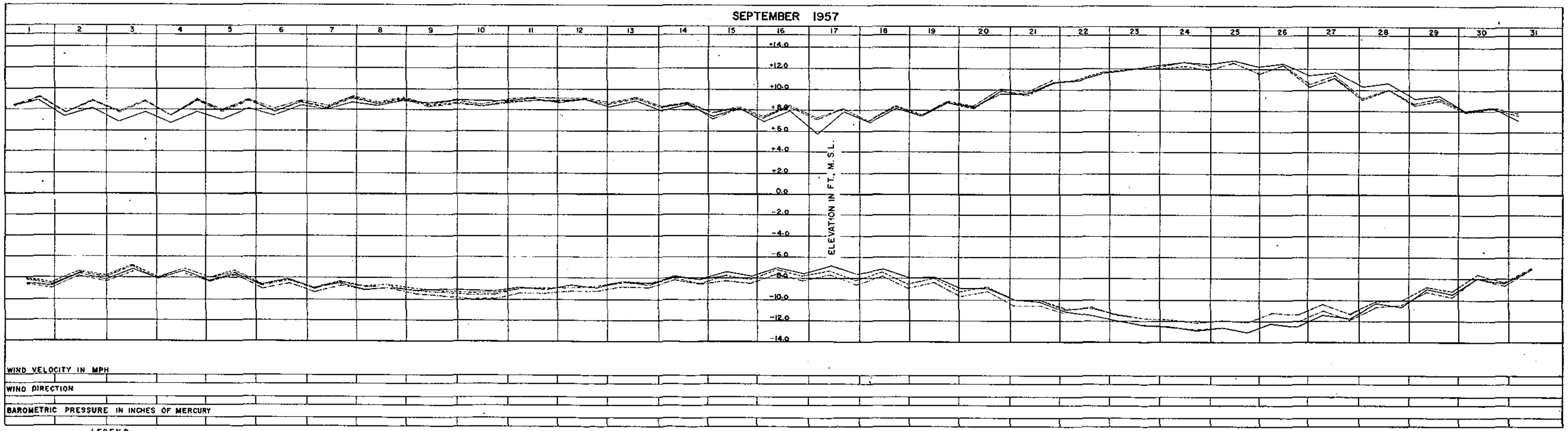


LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - - Eastport, Maine
- —·—·— Falls, (temporary)

NOTES

(Falls) Started 12·27-2
23·35-8 to 05·58-9 No Record



LEGEND

- ———— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - - Wilsons Beach, New Brunswick
- —·—·— Fairhaven, New Brunswick
- —·—·— Letite, New Brunswick

NOTES

(Wilsons Beach) 05·24-25 to 13·14-27 - No Record
(Fairhaven) 02·50-22 to 16·25-23 - No Record
05·31-25 to 18·56-26 - No Record
(Letite) 16·12-17 - No Record

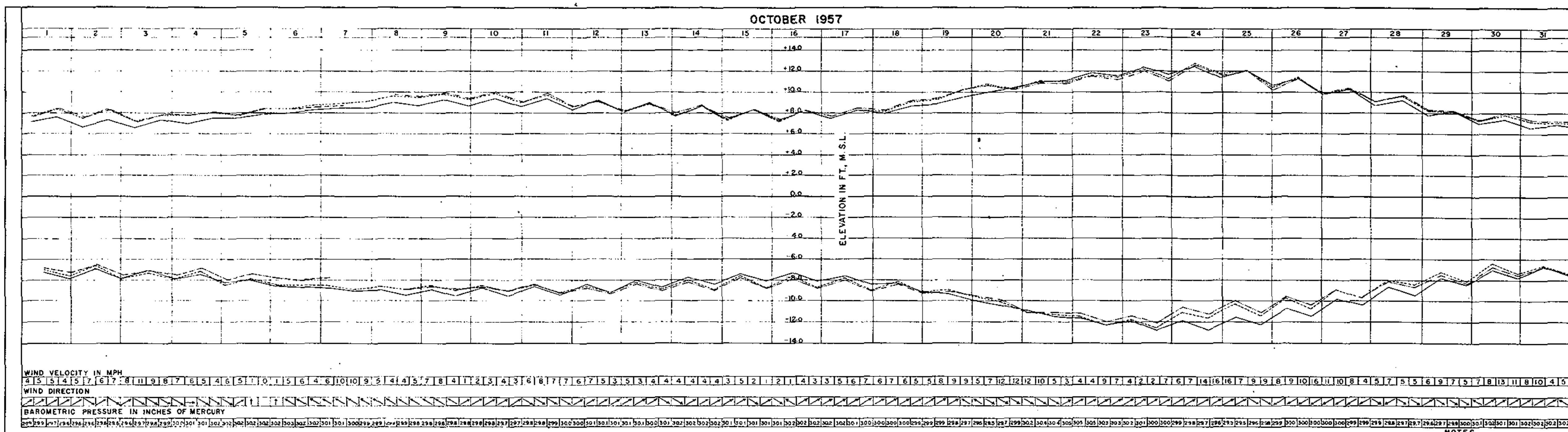
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

SEPTEMBER 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-080

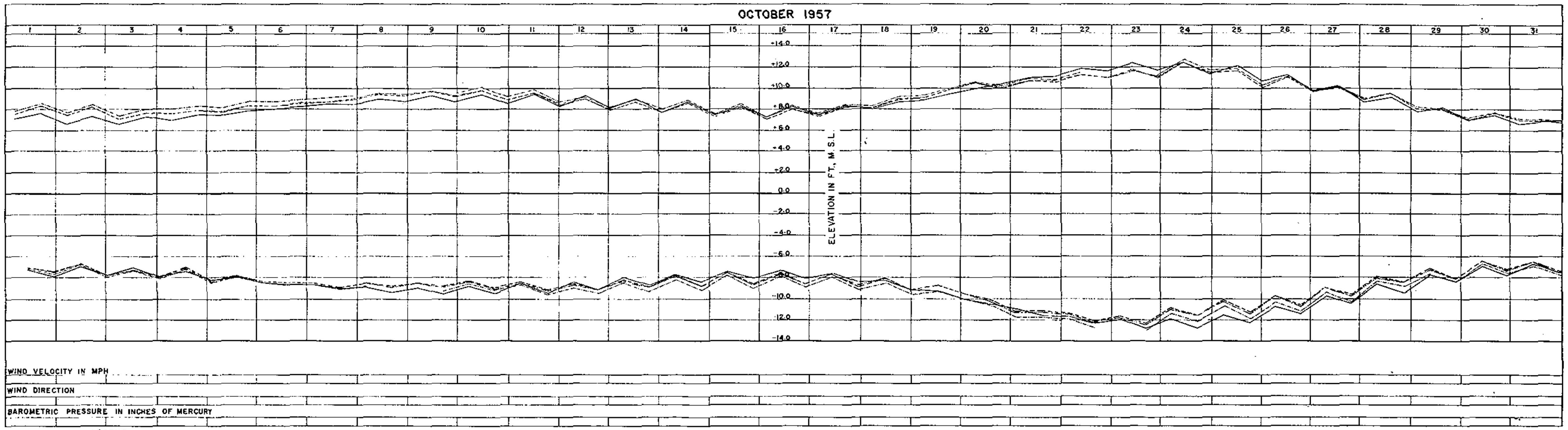


LEGEND

Eastport, Maine - Predicted (U.S.C.& G.S.)
Eastport, Maine
Falls, (temporary)
Neck, (temporary)

NOTES

Falls, Removed 12·06-7
Neck, Started 10·32-8



LEGEND

Eastport, Maine - Predicted (U.S.C.& G.S.)
Wilsons Beach, New Brunswick
Fairhaven, New Brunswick
Letite, New Brunswick

NOTES

(Fairhaven) 04·29-8 to 17·27-9 No Record
09·39-22 to 23·02-23 No Record

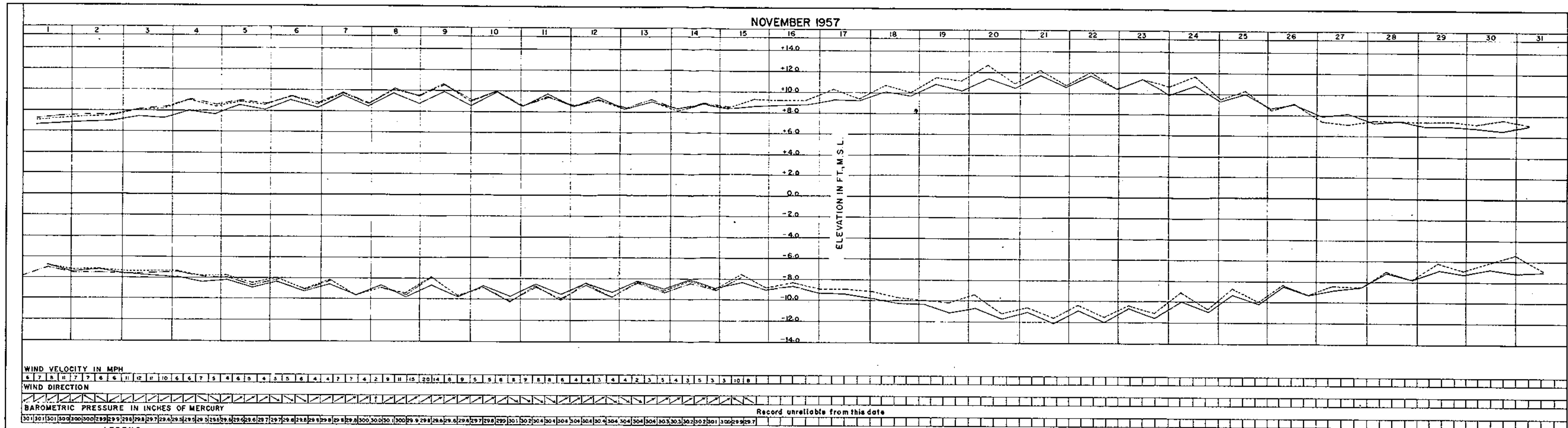
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

OCTOBER 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-081

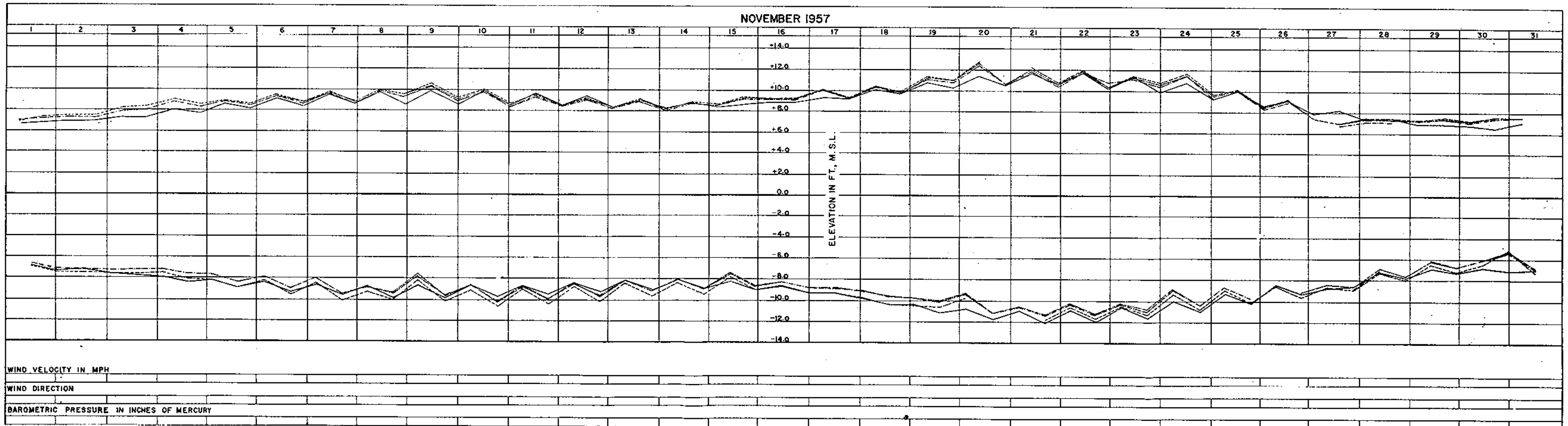


LEGEND

- ——— Eastport, Maine-Predicted (U.S.C.&G.S.)
- - - - - Eastport, Maine
- —·—·— Neck, (temporary)

NOTES

Neck, Removed 10:58-15



LEGEND

- ——— Eastport, Maine- Predicted (U.S.C.&G.S.)
- —·—·— Wilsons Beach, New Brunswick.
- - - - - Fairhaven, New Brunswick,
- —··—·· Letite, New Brunswick.

NOTES

Wilsons Beach	14:00-26	to 15:00-27	No Record
	15:40-28	to 10:19-29	No Record
Fairhaven	09:15-20	to 10:16-21	No Record
Letite	06:54-2	to 14:41-4	No Record

INTERNATIONAL JOINT COMMISSION

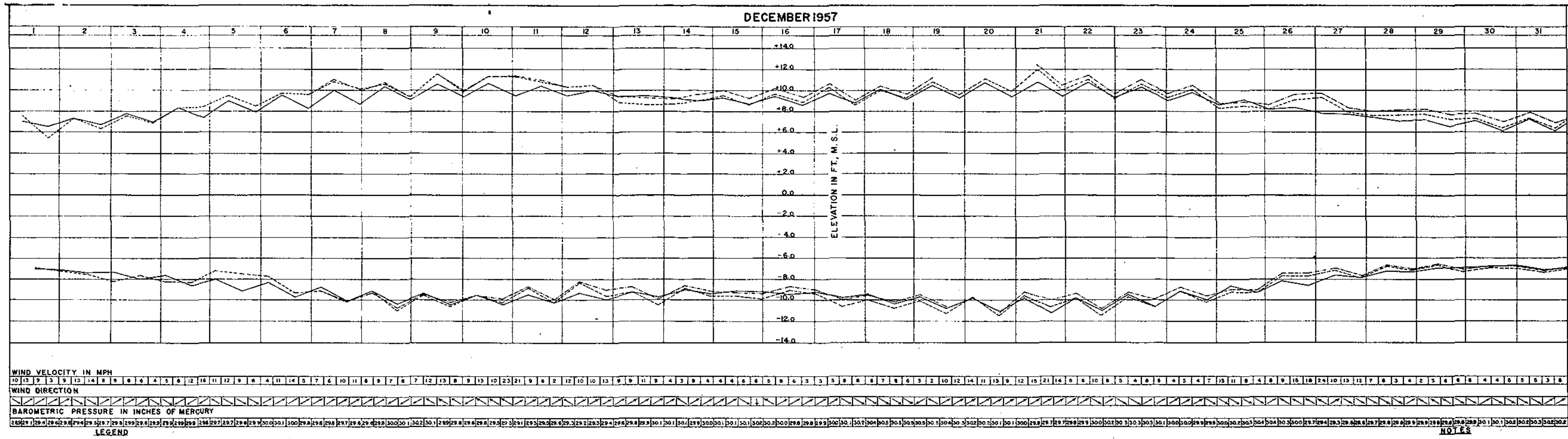
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

NOVEMBER 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-082

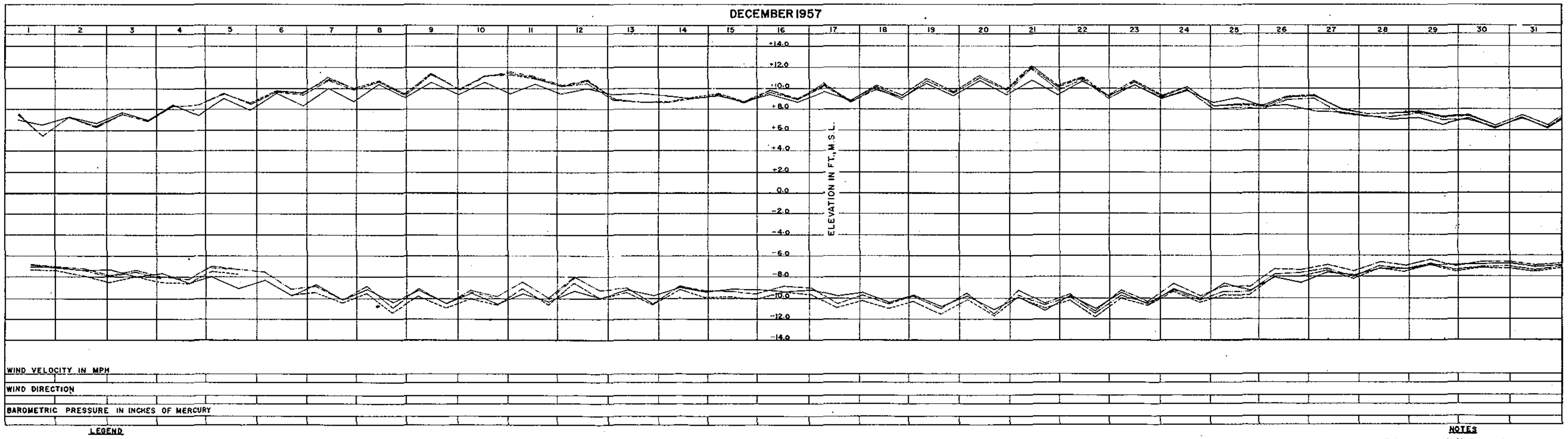


LEGEND

- ——— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - Eastport, Maine
- —·—·— Denbow (temporary)

NOTES

Denbow: Started 16·34-6
15·38-19 to 16·27-20 No Record



LEGEND

- ——— Eastport, Maine-Predicted (U.S.C.& G.S.)
- —·—·— Wilsons Beach, New Brunswick
- - - - - Fairhaven, New Brunswick
- ·—·—· Letite, New Brunswick

NOTES

Fairhaven	21·37-5	to 9·49-6	No Record
Letite (H.W.)	11·19-8	to 0·23-10	" "
	20·09-18	to 22·16-20	" "
(L.W.)	3 52-6	to 18·25-9	" "
	19·12-10	to 20·07-11	" "
	8·31-12	to 4·31-21	" "

INTERNATIONAL JOINT COMMISSION

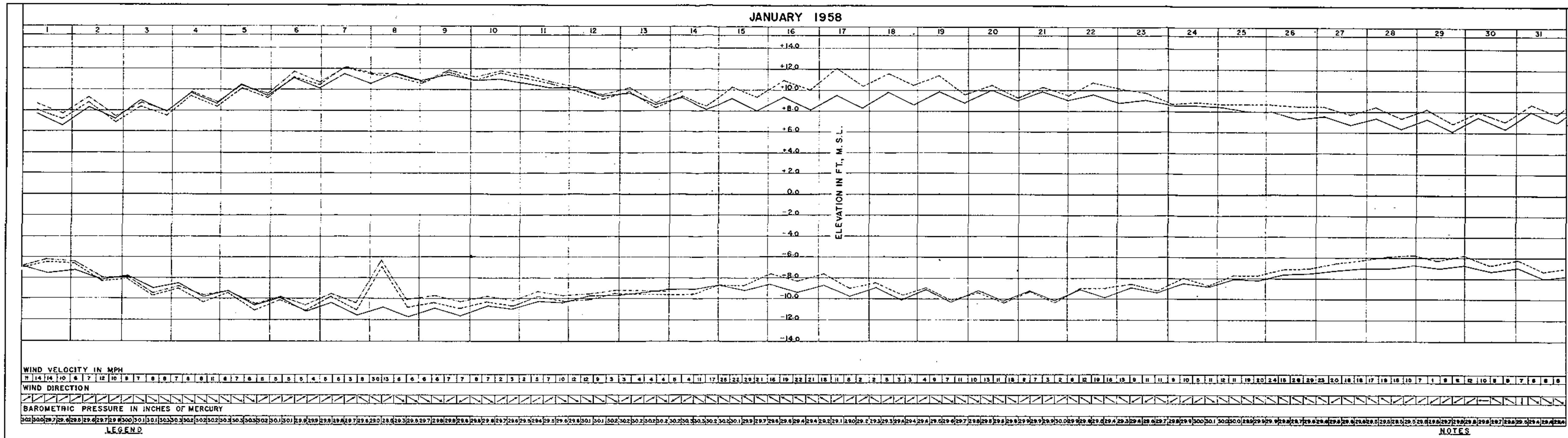
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

DECEMBER 1957

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-083

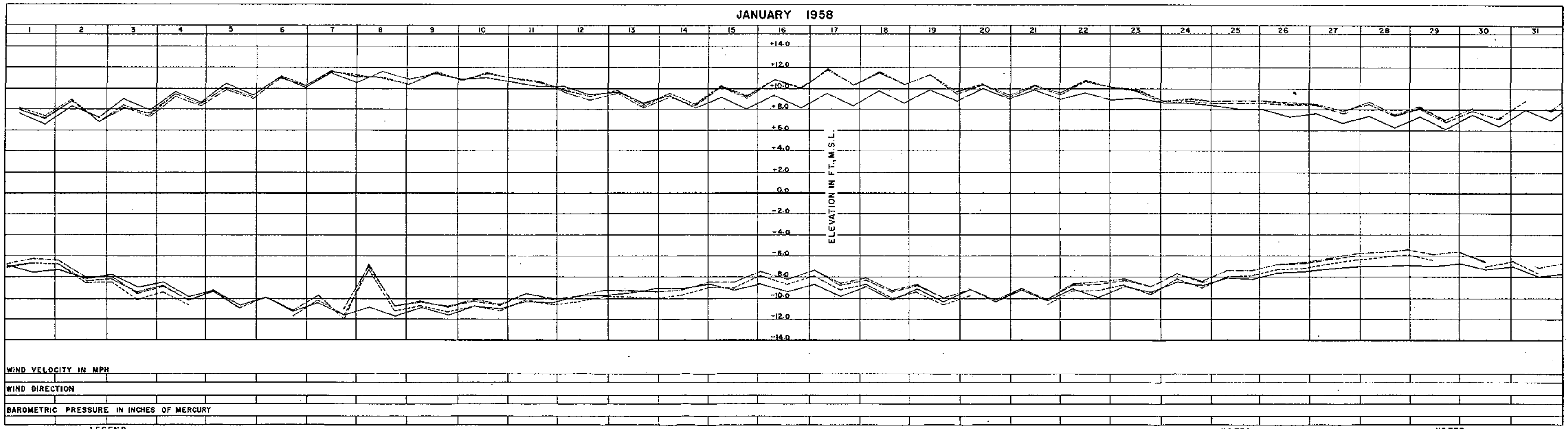


LEGEND

- Eastport, Maine-Predicted (U.S.C.&G.S.)
- Eastport, Maine
- Denbow, (temporary)

NOTES

Denbow-Removed 5-52-14



LEGEND

- Eastport, Maine - Predicted (U.S.C.&G.S.)
- Wilsons Beach, New Brunswick
- Fairhaven, New Brunswick
- Letite, New Brunswick

NOTES

Fairhaven	15-53-4	to	10-49-6	No Record
	11-13-20	"	18-13-21	" "
	8-27-25	"	20-42-25	" "
	17-32-29	"	12-34-30	" "
	13-28-31	"	24-00-31	" "

NOTES

Wilsons Beach	19-49-24	to	1-48-25	No Record
	21-59-27	"	16-44-28	" "
	18-43-30	"	13-22-31	" "
Letite	4-37-6	"	17-14-6	" "
	17-14-6	"	11-31-7	" "
	12-18-30	"	13-21-31	" "

INTERNATIONAL JOINT COMMISSION

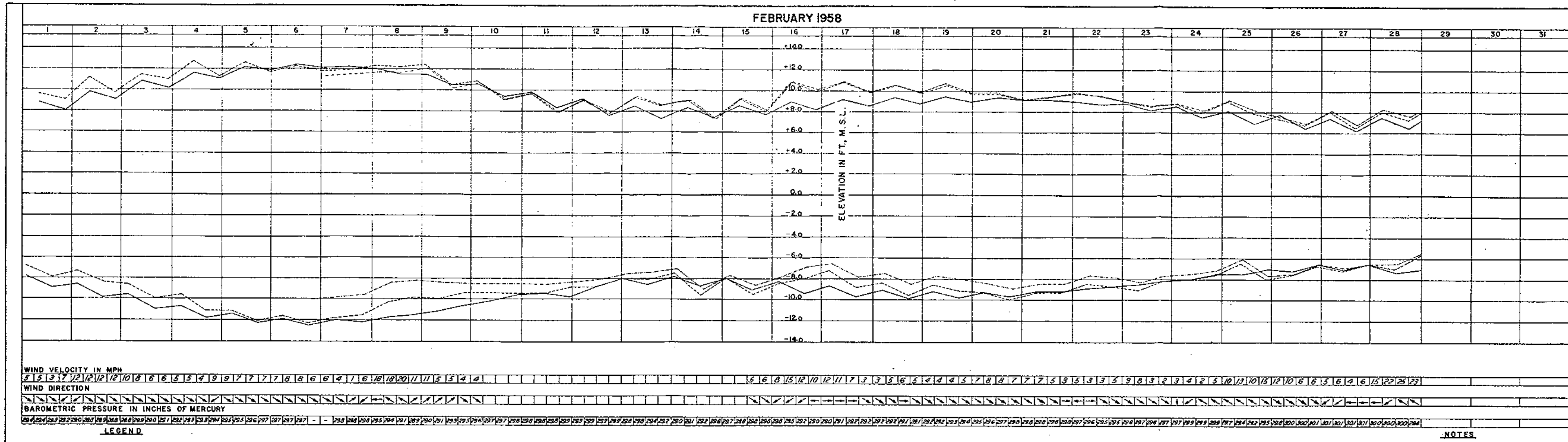
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

JANUARY 1958

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-084

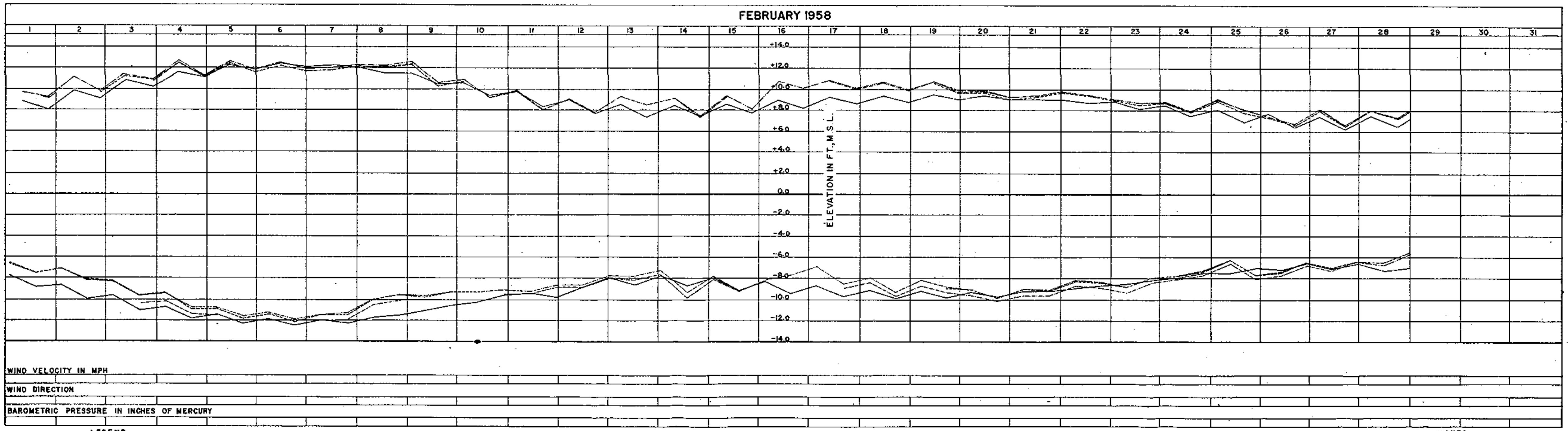


LEGEND

- Eastport, Maine - Predicted (U.S.C.& G.S.)
- Eastport, Maine
- Edmunds, (temporary), Maine

NOTES

(Edmunds) Started 19·50-6



LEGEND

- Eastport, Maine - Predicted (U.S.C.& G.S.)
- Wilsons Beach, New Brunswick
- Fairhaven, New Brunswick
- Letite, New Brunswick

NOTES

(Wilsons Beach) 9·35-10 to 11·12-19 No Record
(Fairhaven) 0·00-1 to 16·27-3 " "
11·23-5 to 19·24-7 " "
2·24-9 to 15·45-10 " "
8·23-15 to 9·54-17 " "

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

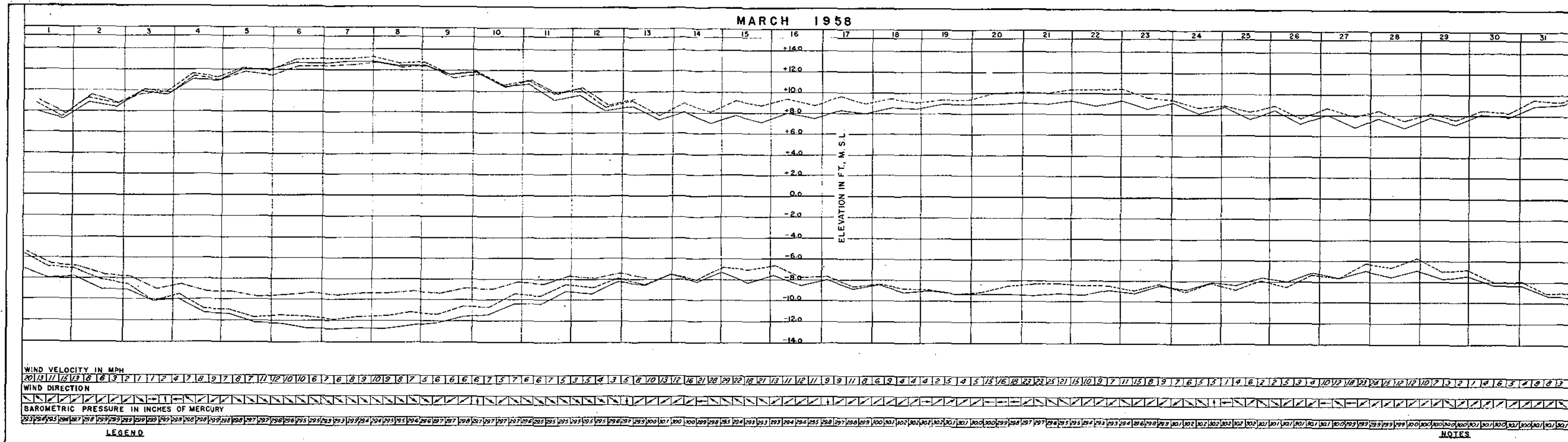
OBSERVED HIGH AND LOW TIDES

FEBRUARY 1958

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. T63-085

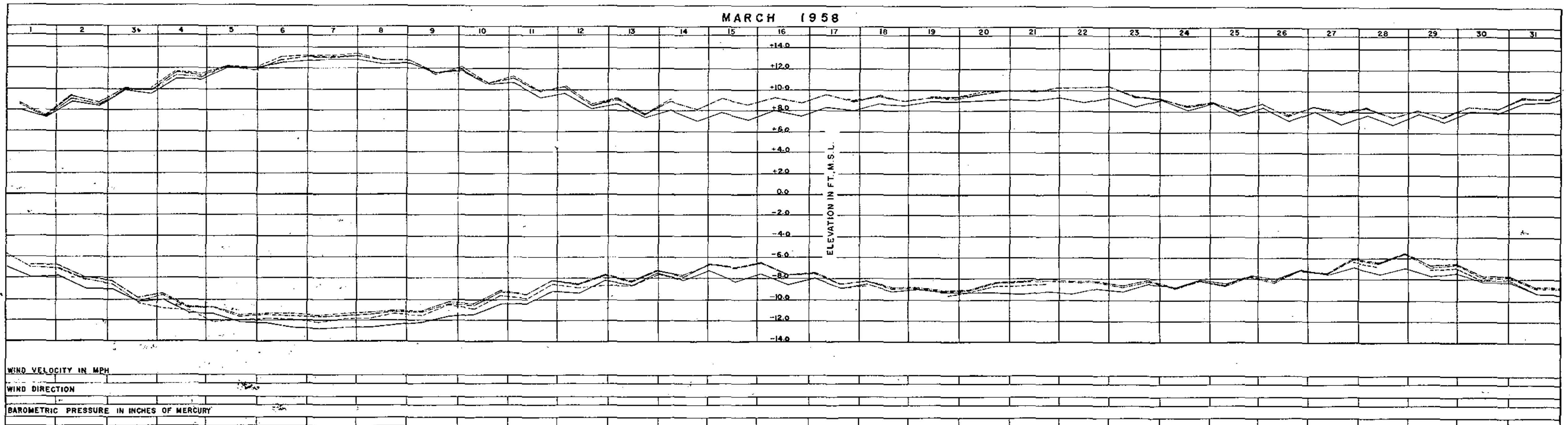


LEGEND

- ——— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - Eastport, Maine
- -·-·-·- Edmunds, (temporary) Maine

NOTES

Edmunds, Removed 12-33-13



LEGEND

- ——— Eastport, Maine - Predicted (U.S.C.& G.S.)
- - - - - Wilsons Beach, New Brunswick
- - - - - Fairhaven, New Brunswick
- -·-·-·- Letite, New Brunswick

NOTES

Fairhaven, 13-52-2 to 14-56-3 No Record
12-30-14 to 15-22-17 " "
3-43-18 to 10-21-19 " "
17-55-21 to 21-34-27 " "

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

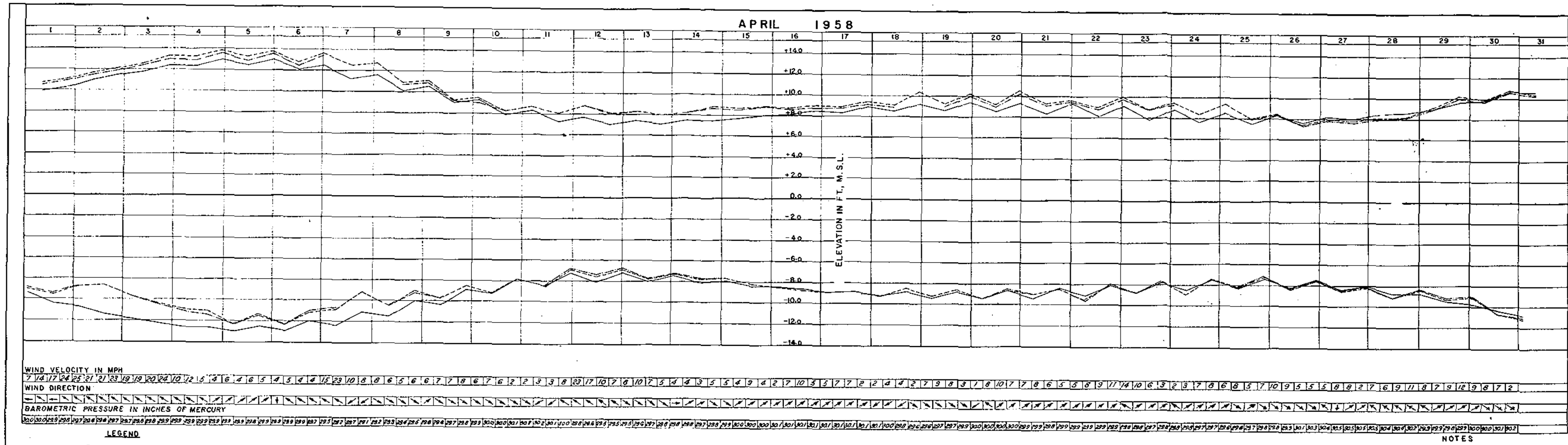
OBSERVED HIGH AND LOW TIDES

MARCH 1958

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. TG3-086

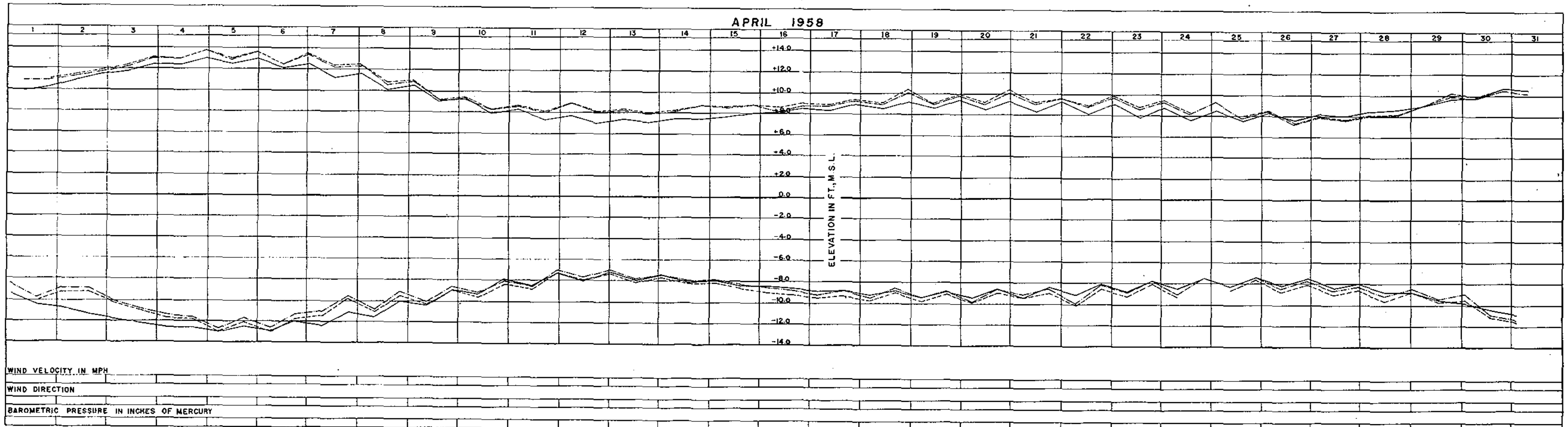


LEGEND

- ——————— Eastport, Maine - Predicted (U.S.C.&G.S.)
- ----------- Eastport, Maine
- —·—·—·— Wilsons Beach, New Brunswick

NOTES

Wilsons Beach 6:51-7 to 7:47-8 No Record
16:40-18 " 10:58-19 " "
1:40-24 " 8:52-25 " "



LEGEND

- ——————— Eastport, Maine - Predicted (U.S.C.&G.S.)
- ----------- Fairhaven, New Brunswick
- —·—·—·— Letite, New Brunswick

NOTES

Fairhaven 14:13-24 to 6:56-25 No Record

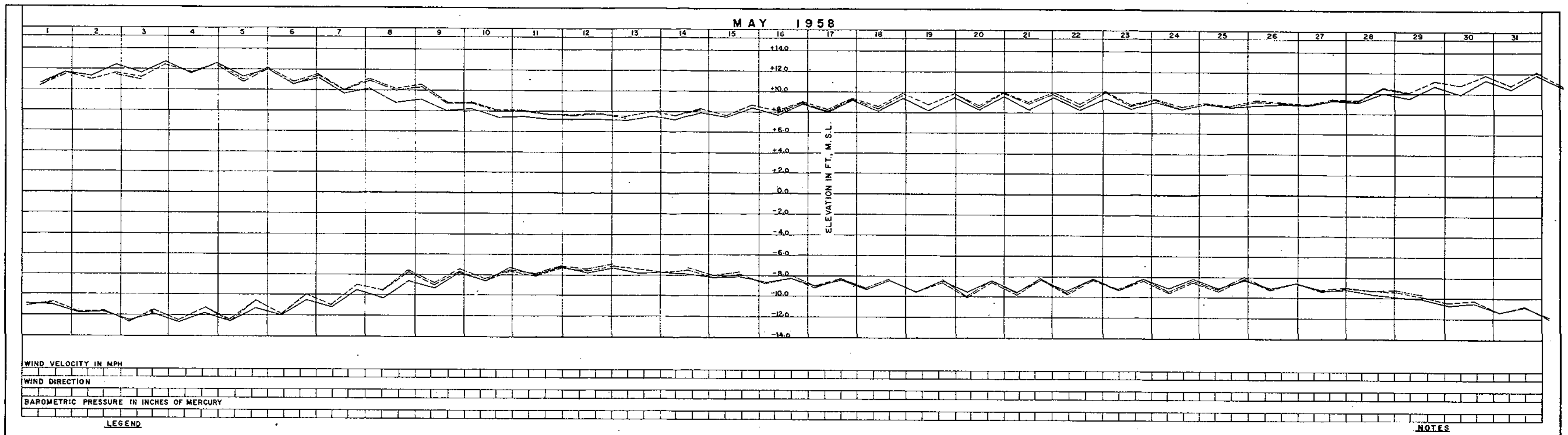
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

APRIL 1958

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-087

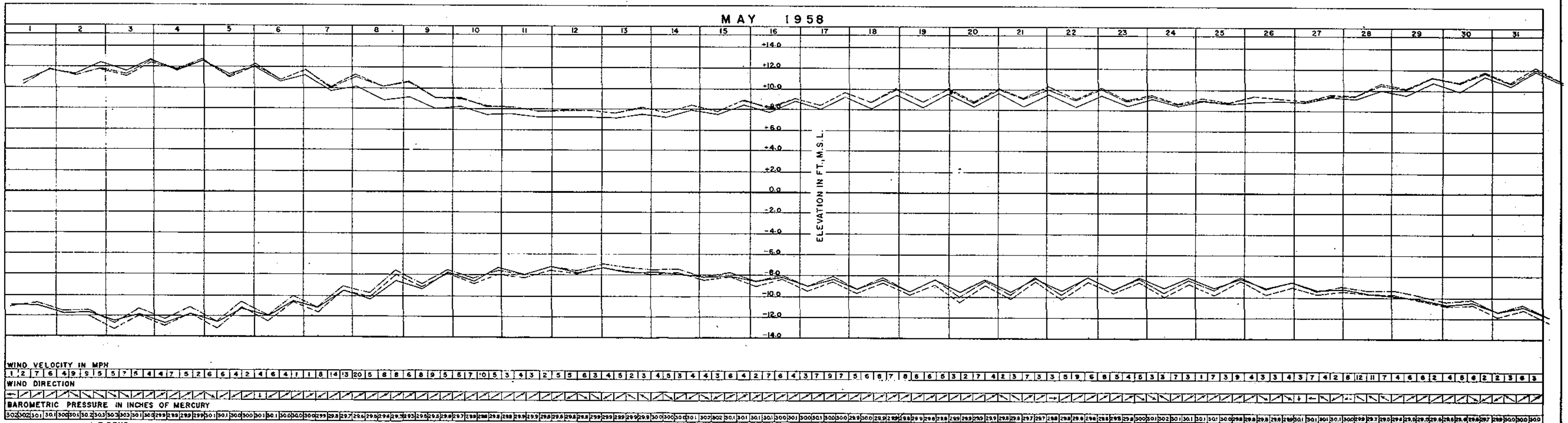


LEGEND

- ———— Eastport, Maine– Predicte (U.S.C.&G.S.)
- - - - - - Eastport, Maine
- —·—·—· Wilsons Beach, New Brunswick

NOTES

Wilsons Beach 3 49-3 to 17 19-4 No Record
6 49-13 " 7 52-14 " "
14 37-15 " 9 22-16 " "
13 19-29 " 0 00-31 " "



LEGEND

- ———— Eastport, Maine– Predicted (U.S.C.&G.S.)
- - - - - - Fairhaven, New Brunswick
- —·—·—· Letite, New Brunswick

NOTES

Fairhaven 8·30-1 to 15·52-2 No Record

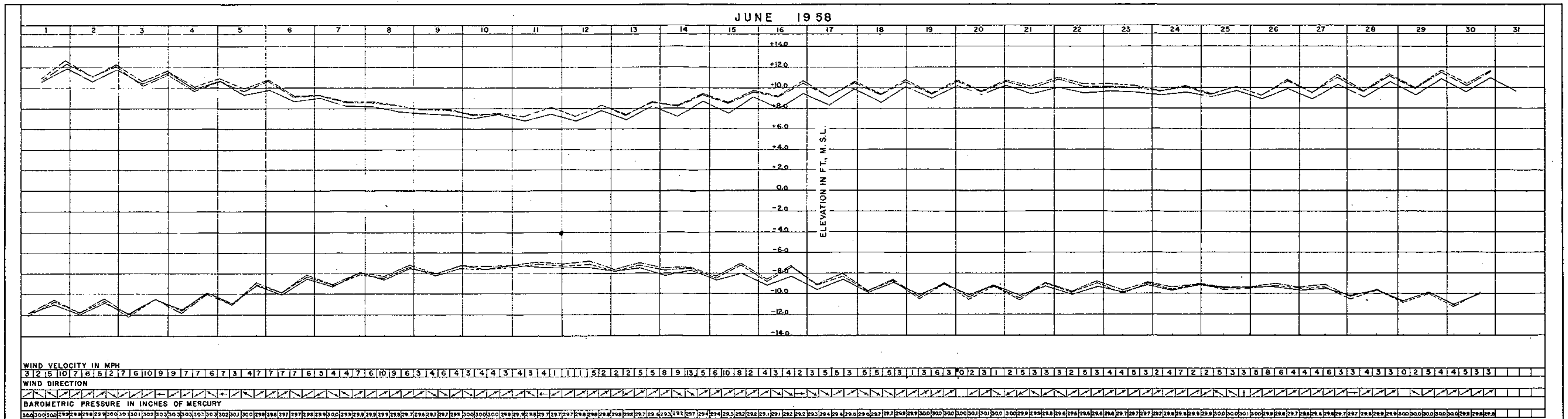
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

MAY 1958

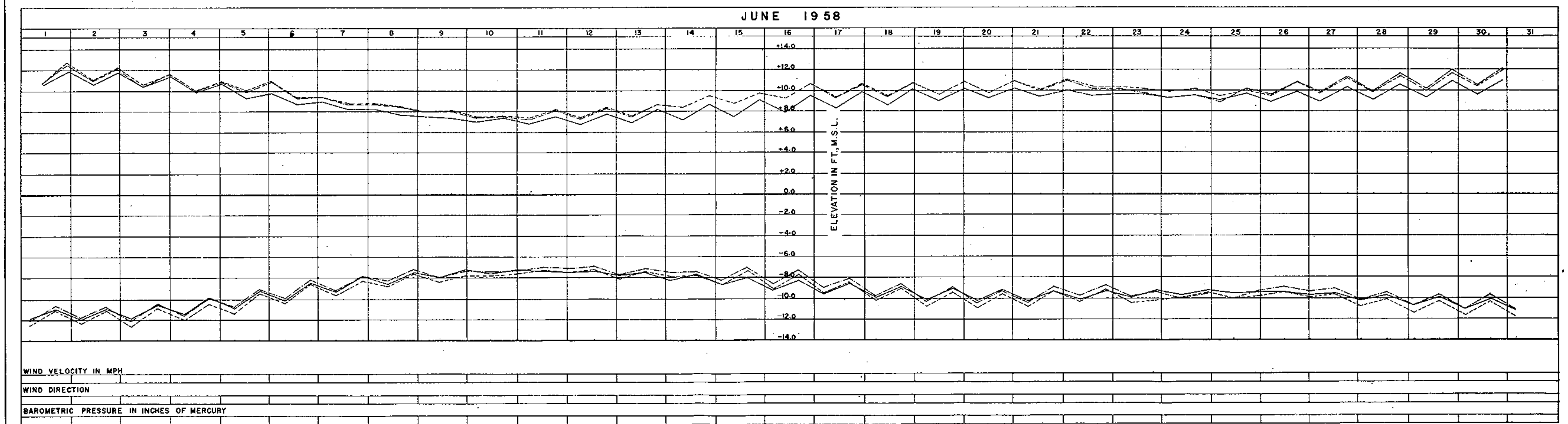
International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-088



LEGEND

- Eastport, Maine – Predicted (U.S.C.&G.S.)
- Eastport, Maine
- Wilsons Beach, New Brunswick



LEGEND

- Eastport, Maine – Predicted (U.S.C.&G.S.)
- Fairhaven, New Brunswick
- Letite, New Brunswick

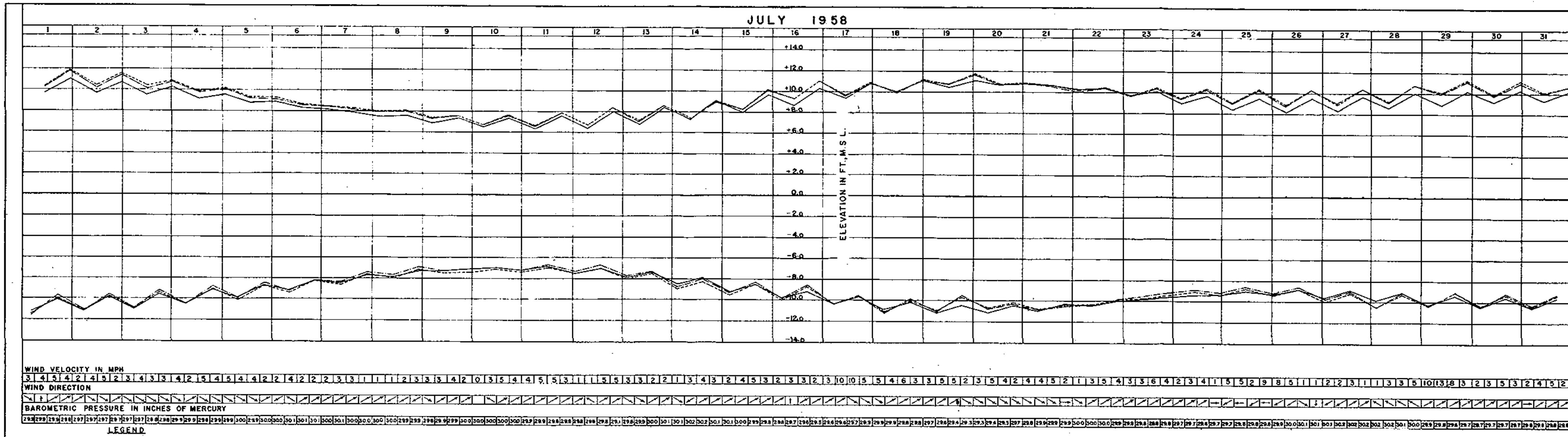
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

OBSERVED HIGH AND LOW TIDES

JUNE 1958

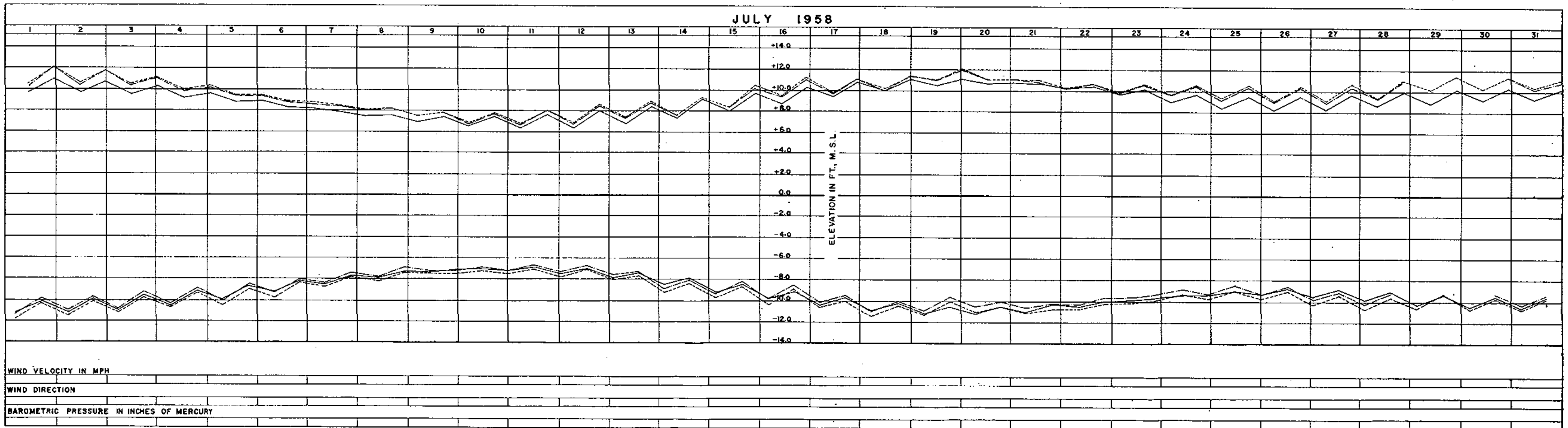
International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-089



LEGEND

———— Eastport, Maine–Predicted (U.S.C.&G.S.)
- - - - - Eastport, Maine
–·–·–·– Wilsons Beach, New Brunswick



LEGEND

———— Eastport, Maine–Predicted (U.S.C.&G.S.)
- - - - - Fairhaven, New Brunswick
–·–·–·– Letite, New Brunswick

NOTES

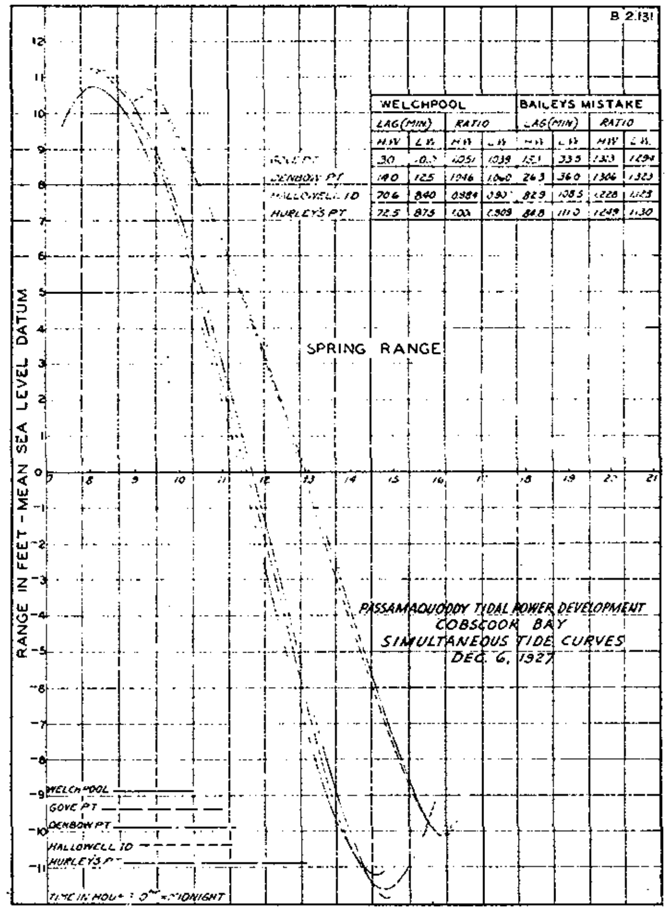
Letite 21-00-28 to 16-41-30 No Record

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

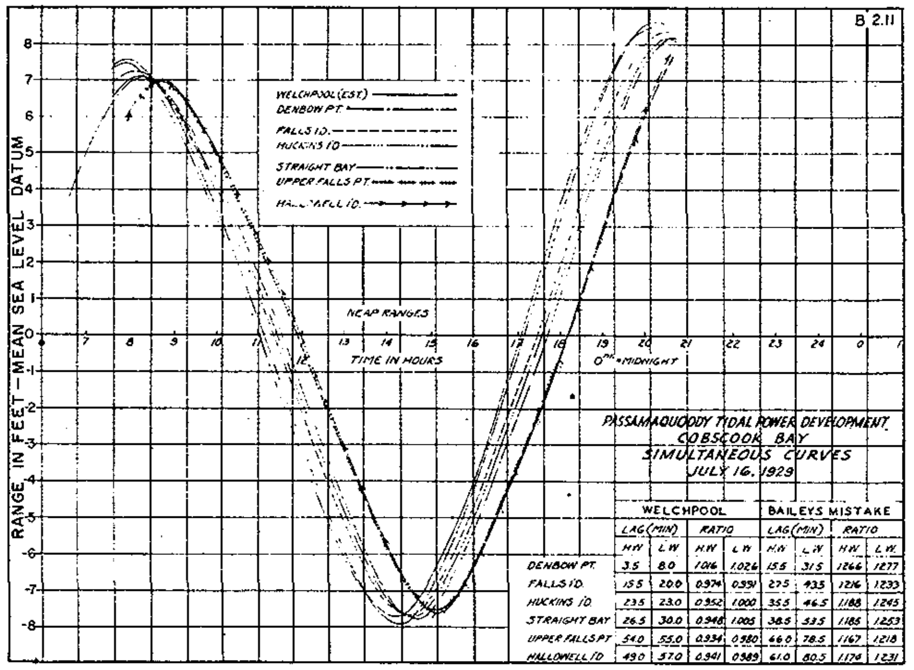
OBSERVED HIGH AND LOW TIDES
JULY 1958

International Passamaquoddy Engineering Board

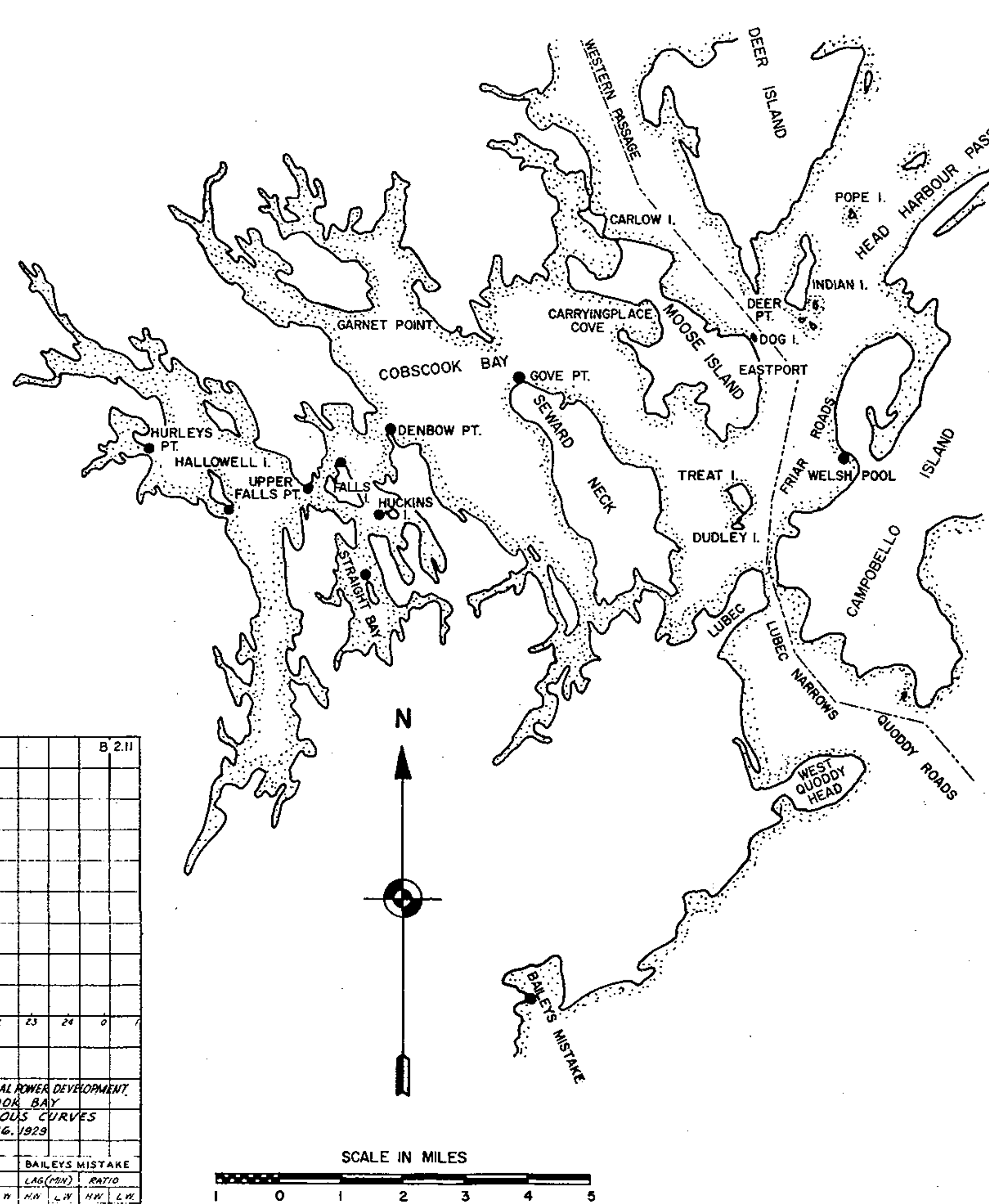
SEPTEMBER 1959 Dwg. No. TG3-090

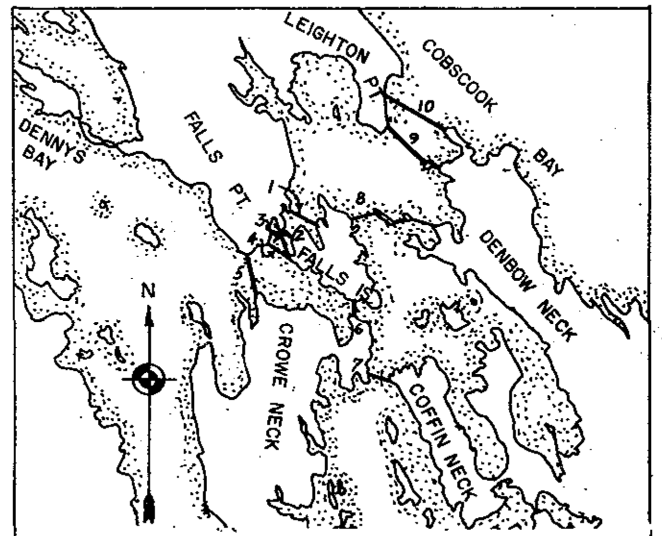


	WELCHPOOL				BAILEYS MISTAKE			
	LAG (MIN)		RATIO		LAG (MIN)		RATIO	
	H.W.	L.W.	H.W.	L.W.	H.W.	L.W.	H.W.	L.W.
GOVE PT.	3.0	[illegible]	1.051	1.039	[illegible]	33.5	1.313	1.294
DENBOW PT.	14.0	12.5	1.046	1.060	26.3	36.0	1.306	1.323
HALLOWELL ID.	70.6	84.0	0.984	[illegible]	82.9	108.5	1.228	1.125
HURLEYS PT.	72.5	87.5	1.00	0.909	84.8	111.0	1.249	1.130



	WELCHPOOL				BAILEYS MISTAKE			
	LAG (MIN)		RATIO		LAG (MIN)		RATIO	
	H.W.	L.W.	H.W.	L.W.	H.W.	L.W.	H.W.	L.W.
DENBOW PT.	3.5	8.0	1.016	1.026	15.5	31.5	1.266	1.277
FALLS ID.	15.5	20.0	0.974	0.991	27.5	43.5	1.216	1.233
HUCKINS ID.	23.5	23.0	0.952	1.000	35.5	46.5	1.188	1.245
STRAIGHT BAY	26.5	30.0	0.948	1.005	38.5	53.5	1.185	1.253
UPPER FALLS PT.	54.0	55.0	0.934	0.980	46.0	78.5	1.167	1.218
HALLOWELL ID.	49.0	57.0	0.941	0.989	61.0	80.5	1.174	1.231





SECTION NO.	AREA - LOW TIDE IN SQ. FT.	AREA - HIGH TIDE IN SQ. FT.
1	16,900	30,000
2	17,350	27,600
3	10,700	27,200
4	10,700	27,200
5	32,000	63,000
6	9,800	22,700
7	7,100	21,800
8	25,000	65,000
9	52,200	97,800
10	58,700	110,200

ELEVATION OF HIGH TIDE IS TAKEN AS ½ SPRING RANGE AT CUMMING'S COVE FOR YEAR OF OCT 1926 THRU SEPT 1927. RANGE = 24.10. ELEVATION OF HIGH TIDE = +12.05 FT. MEAN SEA LEVEL DATUM. ELEVATION OF LOW TIDE = -12.05 FT. M.S.L.

PASSAMAQUODDY TIDAL POWER DEVELOPMENT
BASIC DATA
CRITICAL CROSS SECTIONS
FALLS ISLAND VICINITY

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

SLOPES IN POOL AREAS

FALLS IS., COBSCOOK BAY, ME.
DATA FROM COOPER'S STUDIES
International Passamaquoddy Engineering Board

SEPTEMBER 1959 — Dwg. No. TG3-098

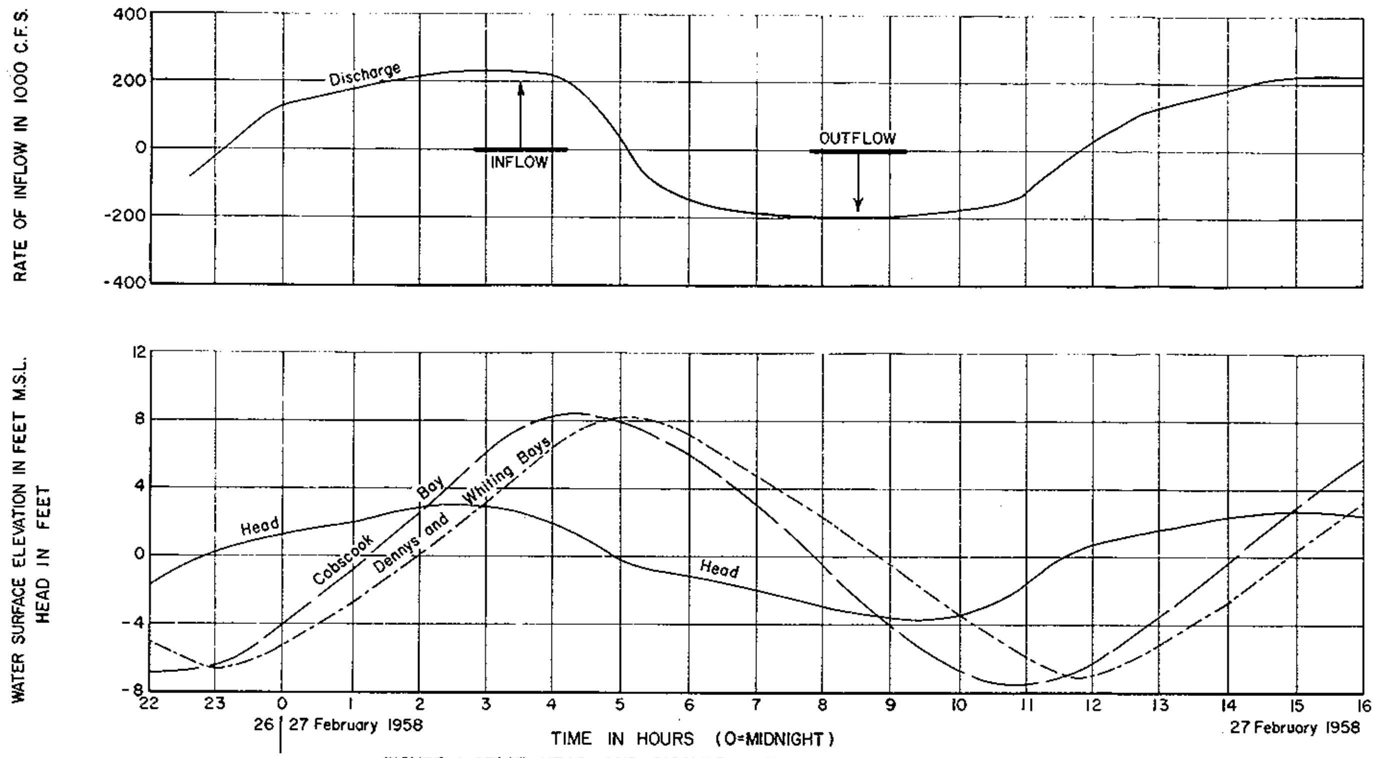


FIGURE 1-STAGE, HEAD, AND DISCHARGE CURVES FOR A NEAP TIDE

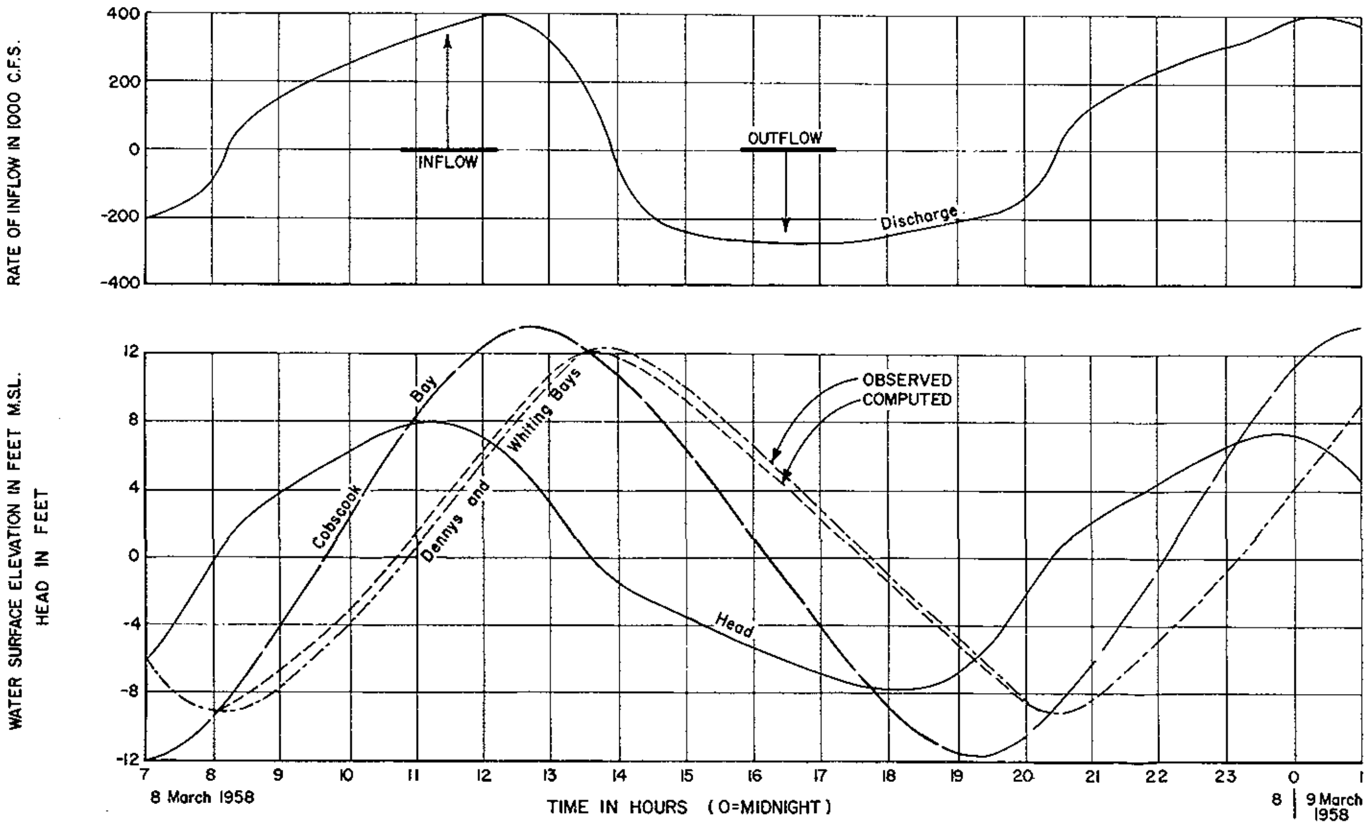


FIGURE 2-STAGE, HEAD, AND DISCHARGE CURVES FOR A SPRING TIDE

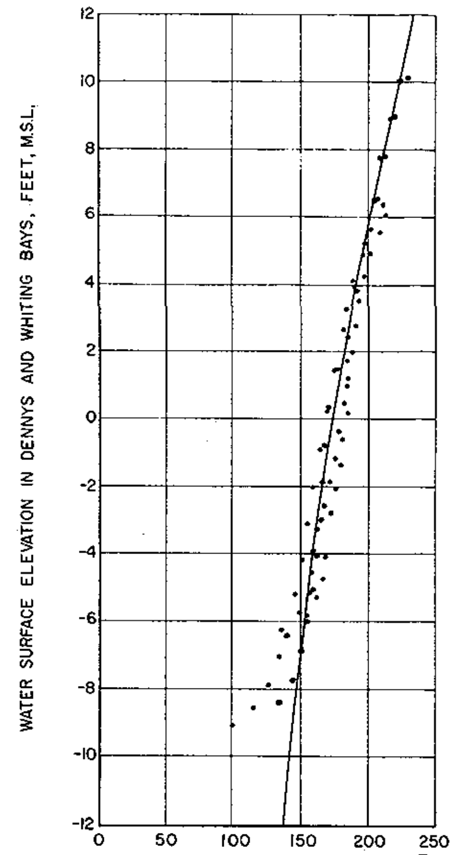


FIGURE 3-COEFFICIENTS FOR INFLOW

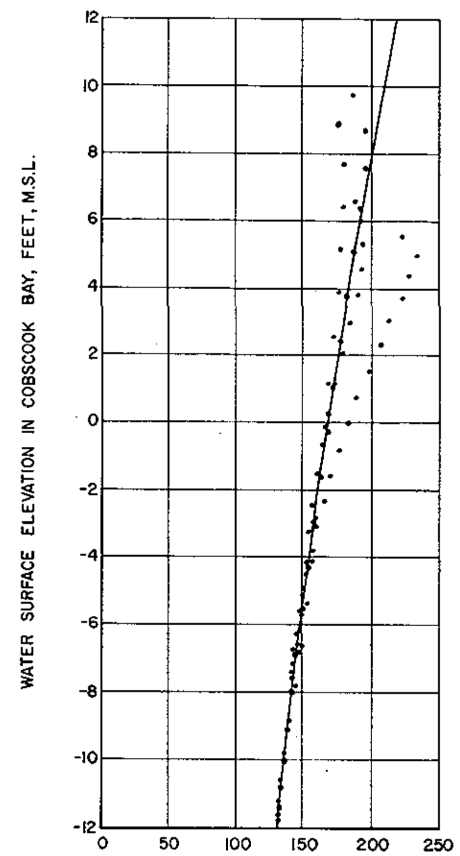


FIGURE 4-COEFFICIENTS FOR OUTFLOW

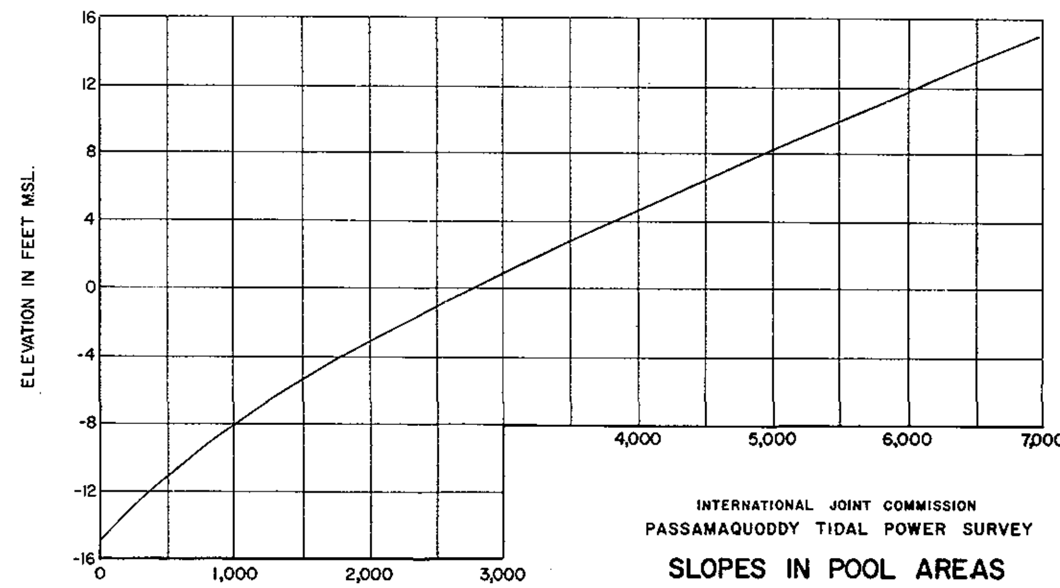


FIGURE 5-STORAGE CURVE
DENNYS AND WHITING BAYS

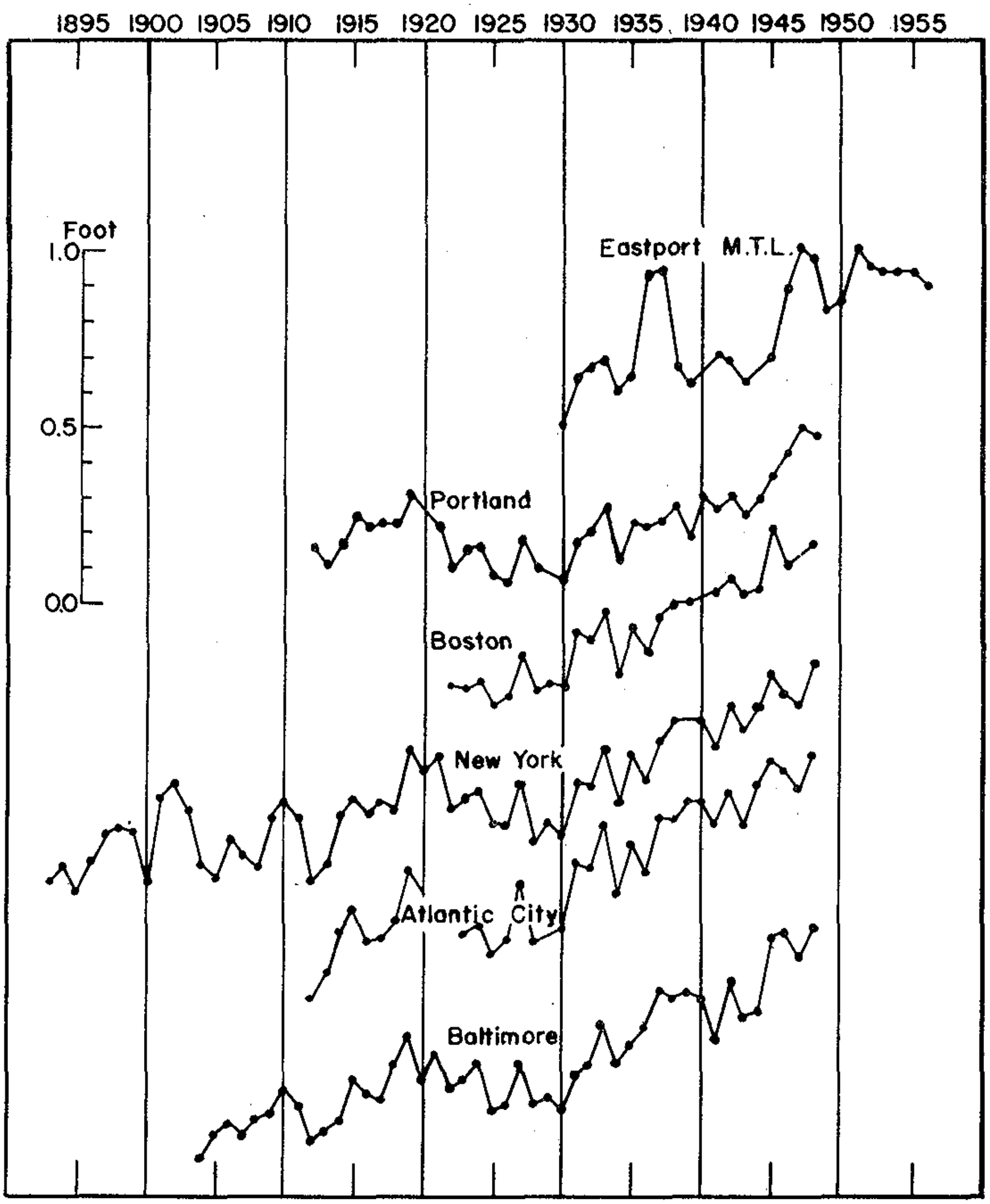
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

SLOPES IN POOL AREAS

FALLS IS., COBSCOOK BAY, ME.
1958 DATA AND ANALYSIS

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-099



NOTE:

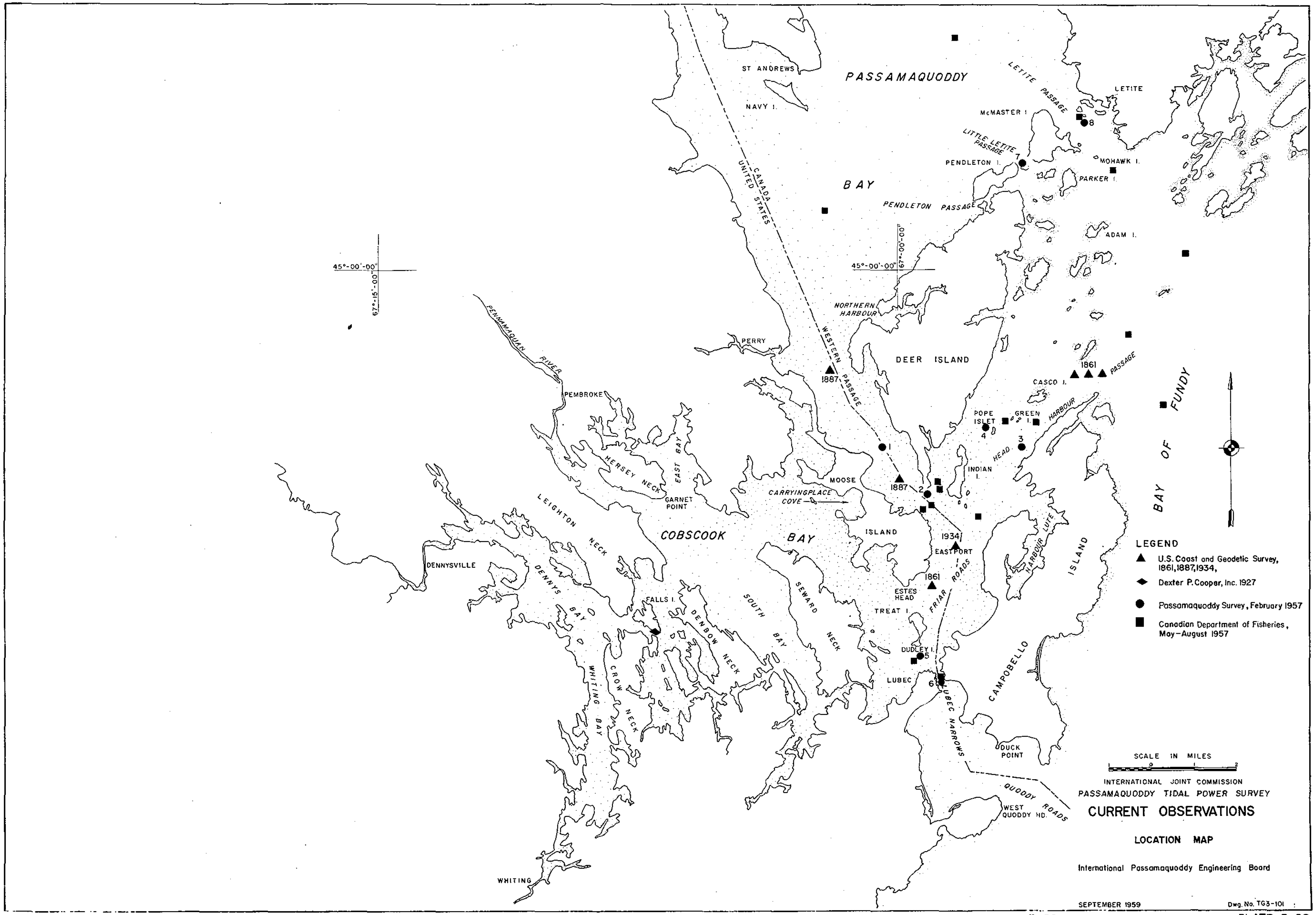
Copied from "Tidal Datum Planes" by the U.S. Coast and Geodetic Survey, 1951, with yearly mean tide level for Eastport added.

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

YEARLY SEA LEVEL
ATLANTIC COAST

International Passamaquoddy Engineering Board

SEPTEMBER 1959 Dwg. No. TG3-100



INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

CURRENT OBSERVATIONS

LOCATION MAP

International Passamaquoddy Engineering Board

SEPTEMBER 1959

Dwg. No. TG3-101

PLATE 3-28